GRAIN

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PREFACE

Very few books on goods of any kind are written for the needs of those engaged in Commerce. Most books on the Cereals, for instance, are concerned either with agriculture, milling, or economics. This book deals with the problems that the importer meets, such as the establishment of standards of quality, the effect of moisture on grain, the characteristics of the varieties of grain dealt with in commerce, the loss in weight on storage, and questions of that kind. The chapters form part of a second year's course held at the City of London College for those engaged in the grain trade in the City. No attempt is made in this volume to deal with the business side of the grain trade, that is with the contracts (except in so far as they specifically mention the goods), insurance, documents, and business procedure. These subjects form another part of the Course.

My thanks are due in no formal sense to Dr. Herbert Hunter, who read the proofs, and to Mr. J. Gordon Hay, F. I. C., both of whom gave me much valuable help. I should like also to acknowledge information from Mr. S. K. Thorpe on barley, from Sir Herbert Robson, and from the London Corn Trade Association. Professor Percival's standard handbook on Wheat provided the source for part of Chapter III and most of Chapter VI.

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THE WHEAT SUPPLY

THE increase in the population of the United Kingdom during the past century and a half has provided us with the abiding and difficult problem of food supply. Estimates of the population of the country show that in 1750 there were $6\frac{1}{2}$ million inhabitants, and that during the two previous centuries their numbers had only very gradually risen to this figure. But from then onwards the population has increased progressively to its present figure of about 47 millions.

Population of the United Kingdom.

Year.	*Million inhabitants.*	*Year.*	*Million inhabitants.*	*Year.*	*Million inhabitants.*	*Year.*	*Million inhabitants.*
1570	4·2	1750	6·5	1841	27·0	1891	38·1
1600	4·8	1801	16·3	1851	27·7	1901	42·0
1630	5·6	1811	18·5	1861	29·3	1911	45·4
1670	5·8	1821	21·2	1871	31·8	1914	46·1
1700	6·0	1831	24·4	1881	35·2	1921	46·7

The stimulus which led to this increase was the discovery of the use of steam and the consequent continuous improvements in the manufacturing arts. The pioneer inventions were made in this country which was by chance possessed of rich and conveniently-placed supplies of coal and iron ores. Working with a power-driven machine a given number of men can turn out many times the quantity of goods that another similar group can produce by its own unaided efforts in a given period of time. So that when the goods made by each group come to be traded to each other, the group possessed of the machine finds itself able to exchange its product for that of many such unaided groups.

Agriculture is an art in which even to-day power-driven machinery plays a minor part, although more energy is perhaps expended in tilling and cultivating the soil than in any other

industry; and even if the application of power to agriculture were comparable in its extent with its application to manufactures there would still remain the inexorable change of the seasons controlling the rate of production and the fixed area of suitable land to limit the size of the crop.

The increase in the population of this country is thus seen to be the direct outcome of the exchange of our factory-made goods for agricultural produce from overseas. It is inevitable to conclude from the way the population remained almost stationary or just advanced as methods of husbandry slightly improved prior to the industrial era, that the population had reached the limit set by the area and fertility of the country. Otherwise what factor operated to keep numbers constant when their natural tendency is to augment? No sooner did food from abroad arrive in exchange for our factory-made goods than the population leapt up as the figures indicate. But the country could no longer feed itself.

Decline in wheat production. This increase in numbers, far from being accompanied by a corresponding increase in wheat production, was actually attended by a fall in the production of wheat during the latter half of last century.

The wheat crop for the harvest of 1925 [1] of Great Britain and Ireland amounted to 1,440,500 tons, viz. England and Wales 1,360,000, Scotland 54,000, Northern Ireland 3,500, and the Irish Free State 23,000. The consumption per head of the population averaged over the five-year period 1911–15 amounted to 324 lb. of wheat per annum ($5\frac{1}{2}$ bushels approximately), and

[1] The Ministry of Agriculture publishes annual Agricultural Statistics in three parts. Part I is a Report on Acreage; Part II is on Production, and Part III is on Prices and Supplies.

Part I, Acreage, is compiled from returns made on or before the 4th June by farmers, and is published in December of the same year. Part II, Production, is an estimate of weight and yield per acre of the main crops compiled from the figures obtained at harvest time by a staff of 350 crop reporters. It is published in March of the succeeding year. Part III, Prices and Supplies, is compiled from the figures of official market reporters and published in March or April of the succeeding year. During August of the year under consideration a preliminary statement is published summarizing the main results subsequently incorporated in Part I, and in early November a preliminary statement summarizing those subsequently incorporated in Part II.

we may assume that this is reasonably constant, although there are some indications that it is declining.

At this rate Great Britain and Ireland could supply bread to just less than 10 million inhabitants, supposing they were content with bread made entirely from home-grown wheat.

This, too, understates our present dependence on external supplies, for it is probable that no more than 55 per cent., certainly not more than 60 per cent., of home-grown wheat reaches the mills. Wheat for seed and food for poultry and pigs accounts mainly for the balance. This reduces the actual household supplies of bread, biscuits, and flour from home-grown wheat to a quantity sufficient to feed only 6 or 7 million people.

The population of Great Britain and Ireland to-day is 47 millions. It follows, therefore, that we must import wheat or flour to feed 40 million people, or approximately 26 million quarters annually, to maintain the accustomed level of material comfort.

This unstable condition has been arrived at not alone on account of the increase in population, but also through the decline in wheat production in Great Britain and Ireland since the fifties of last century. The following table shows the extent to which the acreage under wheat has gradually shrunk:

Acreage, yield per acre, production, and price of Wheat in the United Kingdom since 1770.

Date or Period.	*Acreage in thousands.*	*Yield per acre in bushels.*	*Production in thousand quarters.*	*Price per qr.* s. d.	*Remarks.*
	England and Wales only.				
1770	2,795	24	—	—	(Gregory King's estimate)
1810	3,160	21	—	—	(W. T. Comber, 1808)
1833	3,250	?	—	—	(A. P. Pebrer)
	United Kingdom.				
1852–3 to 1859–60	4,092	$28\frac{3}{4}$	14,554	—	(Lawes and Gilbert, *J. R. Agr. Soc.* of England, 1893.) Eight-year averages
1860–1 to 1867–8	3,753	$28\frac{7}{8}$	13,523	—	
1868–9 to 1875–6	3,788	$27\frac{1}{8}$	12,900	51/8	
1876–7 to 1883–4	3,091	$25\frac{3}{4}$	9,794	44/10	

Date or Period.	*Acreage in thousands* *United Kingdom.*	*Yield per acre in bushels.*	*Production in thousand quarters.*	*Price per qr.* *s. d.*	*Remarks*
1884–5 to 1891–2	2,513	$29\frac{7}{8}$	9,365	32/2	Official statistics averaged
1892–3 to 1899–1900	1,897	30	7,114	26/11	
1900–1 to 1907–8	1,689	$31\frac{3}{4}$	6,724	28/9	
1908–9 to 1913–14	1,891	$31\frac{3}{4}$	7,513	33/5	Six-year average
1915	2,335	31·7	9,239	52/10	
1916	2,053	29·1	7,472	58/5	Official statistics of the Board of Agriculture
1917	2,103	30·6	8,040	75/9	
1918	2,793	33·3	11,643	72/10	
1919	2,370	29·2	8,655	72/11	
1920	2,979	28·7	7,104	80/10	
1921	2,084	35·4	9,224	71/6	
1922	2,073	31·5	8,156	47/10	
1923	1,838	31·8	7,308	42/2	
1924	1,632	32·4	6,600	49/3	
1925	1,574	32·9	6,483	52/2	

The reasons for this decline are mainly two: first of all the opening up of the virgin wheat lands of North America which led to cheaper supplies than we could produce. This is reflected in the progressive decline in prices from 64*s.* 5*d.* per qr. in 1867 to 22*s.* 4*d.* per qr. in 1904. Secondly, the decline is due to the inferior bread-making quality of home-grown wheat, when matched against the bulk of imported wheat. This inferiority is reflected in the relatively lower price of English wheat.[1] These two causes have made wheat growing unprofitable at home except on unusually suitable wheat lands. Each of these causes is susceptible of detailed analysis. Their gradual operation has had the effect of reducing the acreage under wheat from 4,214 thousand acres in 1857, the maximum acreage ever recorded, to 1,574 thousand acres in 1925, the smallest area ever put down to wheat. The maximum recorded harvest was that of 1864, amounting to 18,204 thousand quarters, and the minimum that of 1904, amounting to 4,739 thousand quarters. Although the yield per acre appears to have risen gradually, it must be remembered

[1] 9 November 1925. London Corn Exchange Quotations:

English: New f.o.r. 504 lb. 49*s.* 50*s.* 6*d.*

Foreign: No. 1. Northern Manitoba, 496 lb. arrived ex ship 57*s.* 6*d.*

No. 2. „ „ „ „ „ 56*s.* 6*d.*

No. 3. „ „ „ „ „ 55*s.* 6*d.*

that poorer wheat lands were cultivated when larger acreages were the rule, and even then individual years showed very high yields. Thus the yield in 1864 was $39\frac{3}{8}$ bushels per acre and in 1855 $35\frac{3}{8}$ bushels per acre.

In consequence of this decline in production, coupled with an increase in population, we must import upwards of 26 million quarters of wheat annually, or half a million quarters a week, to meet our requirements of breadstuffs.

Imports of grain and flour. Figures showing the daily arrivals of grain (as of other goods) at the chief ports of the country are published daily in the Customs Bills of Entry. Complete returns from all ports are required by law to be sent to the Statistical Office. Digests of these figures are published about the 12th of each month under the title *Accounts relating to Trade and Navigation,*[1] and generally referred to as The Board of Trade Returns.

From these records it will be seen that in the last few years our supplies have come from Canada to the extent of from 28 to 33 per cent., 26 to 31 per cent. from the United States, from 12 to 20 per cent. from the Argentine, from 5 to 17 per cent. from Australia, and from 8 to 12 per cent. from India, the figures being approximate percentages by weight.

The change in the orientation of sources of supply is illustrated in the following tables :

Imports of Wheat into the United Kingdom in 1913, 1923, 1924, and 1925 in thousand cwt.

	1913.		1923.		1924.		1925.*	
Total (000 *cwt.*)	105,878	*% of*	100,470	*% of*	117,421	*% of*	97,733	*% of*
(000 £.)	£43,849	*total.*	£53,568	*total.*	£69,004	*total.*	£68,457	*total.*
Canada	21,288	20.6	28,487	28.3	38,769	33.0	29,819	30.3
U.S.A.	34,068	32.2	31,462	31.2	30,321	25.8	27,205	27.8
Australia	10,127	9.6	4,654	4.6	10,871	9.2	16,306	16.7
Argentine	14,756	14.0	21,026	20.9	24,022	20.25	11,960	12.25
India	18,766	17.75	12,230	12.2	9,816	8.3	7,324	7.5
Russia	5,011	4.75	151	0.1	753	0.6	1,265	1.3
Chile	765	0.75	3	—	1,784	1.5	897	0.9
Iraq	(10)	—	1,230	1.2	426	0.4	—	—

* Excluding the Irish Free State.

[1] The comprehensive *Annual Statement of Trade* is published in October of the year succeeding that reviewed. The December number of the monthly *Accounts relating to Trade and Navigation* (4*s.* 6*d.*) published in January contains a summary of the imports and exports for the year just past.

Other countries from which small supplies are derived in good years include Germany, Rumania, France, Persia, Egypt, and Uruguay.

Imports of Flour into the United Kingdom in 1913, 1924, 1925, and 1926 in thousand cwt.

	1913.		1924.		1925.		1926.	
Total (000 *cwt.*)	11,978	*% of*	11,046	*% of*	9,113	*% of*	10,660	*% of*
(000 £.)	£6,348	*total.*	£8,325	*total.*	£8,256	*total.*	£8,806	*total.*
Canada	4,169	34·8	5,246	47·7	4,212	46·2	5,385	50·5
U.S.A.	6,157	51·4	3,608	32·8	2,760	30·3	2,732	25·6
Australia	349	2·8	1,629	14·4	1,487	16·3	1,290	12·1
Argentina	192	1·6	305	2·7	410	4·5	793	7·4

Grain-importing countries. Great Britain is not by any means the only country in which the organization of manufacture has advanced until the numbers engaged in factories and mines have outstripped the capacity of its farmers to feed them. Germany, Belgium, the Netherlands, Italy, Czechoslovakia, and France have long ago reached and passed the strict safety-point of economic development when each could feed itself. Those nations which have taken a leading part during the past 150 years in the exploitation of the resources of the earth have mainly been wheat eaters. Western civilization seems to demand about six bushels of wheat per head to maintain its drive, although Germany maintains her high level of development on a basis of rye-bread.

The consumption of wheat per head is not uniform as between country and country. Thus, omitting seed requirements, the countries named consume the following quantities of wheat per annum per head of the population :

Per capita consumption of Wheat of the chief Importing Countries.

(Broomhall's figures.)

	Bushels.		*Bushels.*
France	7·8	Denmark	4·8
Belgium	6·7	Switzerland	4·5
Italy	6·6	Holland	4·2
United Kingdom	5·7	Austria	3·2
Greece	5·0	Germany	2·2

Thus the problem of forecasting requirements for the year is more complex than it would at first seem, since it depends for

each country on the population and its yearly increase, the average annual consumption per head, the likely extent of the prospective harvest, and the possible use of substitutes such as rye for wheat.

As Oriental races adopt Western manners of life they turn to wheat too, so that the demand from Japan and China is rapidly increasing. The Japanese importation of wheat in 1924 was ten times the average figure for 1909–13. When Germany began her industrial race after the Franco-Prussian War, her wheat imports rose sevenfold in twenty-five years (1870–95) and were doubled again in the next ten years. The demand which each of the confirmed wheat-eating nations makes on countries with wheat to export is equivalent to their respective needs determined by their populations, less their own bread crops, exactly as was shown above for Great Britain. The net imports of such countries are shown in the next Table:

Chief Wheat-importing Countries.

Net imports of Wheat in million quarters.

Country.	*Average of* 1909–1913.	1923.	1924.
Great Britain and Ireland	23·9	23·3	27·2
Italy	7·1	12·4	9·7
France	4·7	6·5	6·6
Belgium	6·8	5·0	5·5
Germany	9·6	2·2	3·3
Japan	0·3	2·0	3·2
Netherlands	1·7	2·5	2·9
Switzerland	2·1	2·2	1·8
Greece	0·9	1·7	1·8
Sweden	0·7	1·2	1·3
Czechoslovakia	—	0·15	1·1
Denmark	0·5	0·7	0·9
Austria	1·1	1·4	0·9
South Africa	0·4	0·6	0·7
Norway	0·9	0·4	0·5
Brazil	1·6	2·3	—

Surplus-grain producing countries. It is fortunate for countries like our own that there are others in the world which still have room to grow more wheat than their manufacturing classes need. The net exports of such surplus-producing countries are as follows:

Chief Wheat-exporting Countries.

Net export of Wheat in million quarters.

Country.	*Average of* 1909–1913.	1923.	1924.
Canada	9·3	30·3	26·8
Argentine	11·1	17·1	20·2
United States	6·6	9·9	18·9
Australia	5·2	4·9	7·4
India	6·0	7·5	3·5
Russia	19·0	1·5	1·1
Hungary	1·2	0·33	0·8
Chile	0·3	0·09	0·7
Rumania	6·1	0·13	0·5

Thus, in spite of the present magnitude of industrial enterprise in the United States and the accompanying increase in her population from 44 millions in 1874 to 115 millions in 1925, her wheat production has not only kept pace with her needs but has regularly provided a large surplus for export. The crop in 1874 when the population was comparable with that of the United Kingdom was 36·5 million quarters, whereas in 1924 it amounted to 109 million quarters, with a surplus for export amounting to 33 million quarters, which represents a record.

Again, in Canada grain production is organized on a basis of vast export. Canada is dominantly agricultural and needs only a third part of her wheat crop to feed her 9 million inhabitants, leaving an available surplus of 35 million quarters for export.

II

NEEDS AND SURPLUSES

WITH few unimportant exceptions the Governments of the various countries of the world make and publish more or less carefully prepared statistics of the kind referred to as undertaken by our own Ministry of Agriculture in the foot-note on p. 2 concerning the acreage and production of grain crops. They also support a central organization at Rome known as the International Institute of Agriculture,[1] one section of which is devoted to the digesting and disseminating of international statistics relating to the main agricultural crops, published in the form of an *International Crop Report* on the Thursday nearest the 20th of each month.

From this publication the official estimates of the grain production of the world are obtainable month by month.

The countries of the world fall, then, into two groups, those which, like England, are dominantly industrial and which are in need of foreign grain, and those which, like Canada, are dominantly agricultural and produce surpluses of grain for export. The surpluses produced by the members of the one group must be adjusted to the needs of the members of the other. This is the complex and absorbing problem of the Grain Trade. It can only be smoothly resolved by operations on highly organized markets situated at strategic centres of supply and demand.

Each of the main factors in the problem has its effect on price, and elaborate and efficient intelligence organizations keep all markets informed of the latest news relating to each factor. Their integrated effect on price is nearly instantaneous over Europe and America.

[1] Founded in 1910. The Russian Soviet Government prepares and publishes crop reports, but these are not yet incorporated in the statistics of the *International Institute Reports*.

The problem is to ensure a day-to-day delivery to the mills of the surplus-needing countries of Europe of such quantities of the various kinds of wheats as they require so that by the end of the *cereal year* [1] the grain harvests of the agricultural countries shall have been evenly distributed among them.

To do this in an orderly and economic manner requires knowledge beforehand of the quantities available for importation for the cereal year and for the immediate future, and of the needs of the mills.

It is one thing to review the statistical position for a year that is past, but quite another to decide the day-to-day purchases from the available market data, many of which by their nature must be estimates. Among the factors which determine the nature of the trade in grain and the price of wheat are considerations arising out of the rotation of the world's harvests.

Time of harvest. The harvests of the world are not everywhere simultaneous, but move northwards across the globe, beginning the year in Australia and the Argentine, passing through India in April, Texas in June, and so on North, till in Great Britain harvest may linger on until November. By that time harvest weather has moved across the globe and the Australian crop is again ready.

It is consequently impossible to say in any given month of the cereal year what the production of wheat in each country is, since in each it is at a different stage of its seasonal development. Yet something like this must be done since prices for delivery ahead require it both on the demand and on the supply side. In consequence, reports, prepared either officially or by private enterprise, of the acreage, then of the state of the crop month by month, with an estimate of the yield, keep the markets informed of the prospective production as the prospects change with the development of the crop.

Further, each surplus-producing country provides crop reports at frequent intervals which are cabled immediately to the main international markets. There are also private organizations, such as Broomhall [2] and Comtelburo Ltd., which supply independent information of the same kind, and throw the official statistics into a daily form for market use.

[1] In Europe: 1 August–31 July. In United States: 1 July–30 June.

[2] The *Corn Trade News*, published daily.

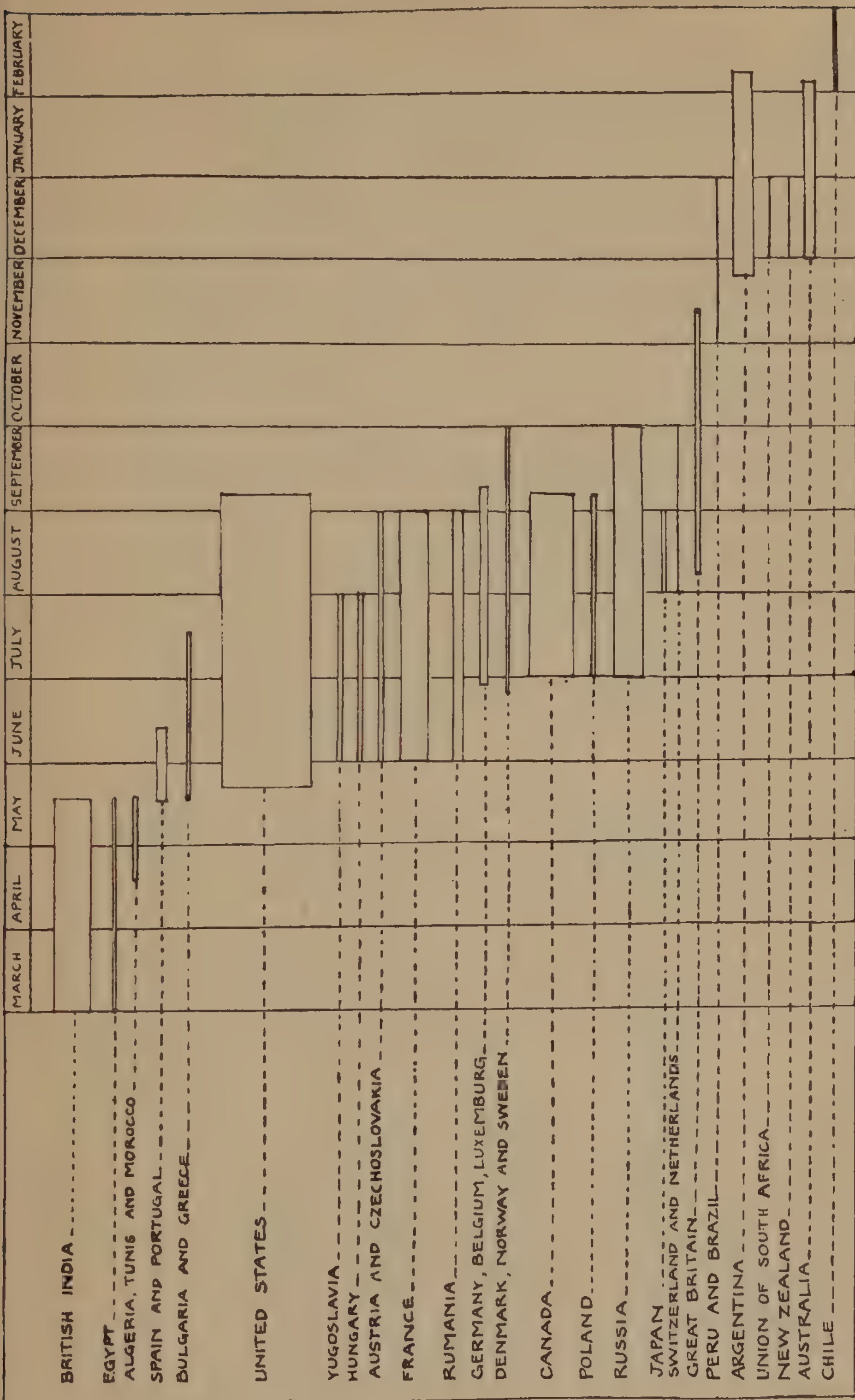

Fig. 1. International Wheat Calendar. The length of each rectangle indicates the harvest period in each country, while the width is in proportion to the average production for the three years 1920–2.

Such official reports are collected and published together as above indicated by the International Institute of Agriculture at Rome each month.

The accompanying table (Fig. 1) from T. D. Hammatt's *Selling American Wheat Abroad* shows the harvest time in each of the important grain-producing countries of the world.

Actually the new crop of wheat from Australia arrives in Europe in April, from the Argentine in March, from India in June, from the United States in August (Winter Wheat) and October (Spring Wheat), and from Canada in November.

It would appear from the fact of the gradual progression of harvest time during the year over the face of the globe that the congested industrial populations of Europe could confidently rely on steadily arriving surpluses first from Australia, then from the Argentine, India, the United States, and North America. And indeed the figures representing the quantities of grain shipped per month from the great producing countries taken as a whole [1] seem to justify that view.

Quarterly Exports of Wheat from Seaboard.

Four-year average 1920–1 to 1923–4.

Quarter.	*Bushels.*	*Per cent. of total.*
July–September	151,923,000	22·9
October–December	158,130,000	23·8
January–March	177,351,000	26·7
April–June	176,495,000	26·6
Total	663,899,000	100·0

But the steadiness of the relays of consignments arriving in Europe which characterizes the international wheat trade is due to a large extent to the evenly-distributed demand for bread-stuffs throughout the year and the marketing methods evolved to meet it. As 75 per cent. of the whole of the world's crop is reaped in the three months June, July, August, its gradual release over the year, involving as it does the holding of stocks, is part of the systematic organization of the trade. The fluctuating supply is regulated to meet the evenly-distributed demand. Besides affording the advantage of steady relays of consignments, the diversity of origin of wheat supplies practically guarantees us against famine, since the chance of a widespread

[1] *Seasonal Aspects of Wheat Marketing.* T. D. Hammatt.

failure of successive harvests in the same year is very remote. With a world-wide field to draw upon, the caprice of nature is no longer the formidable factor it once was. When the harvest is poor in one country for some reason or other, it is balanced by a good crop elsewhere.

Needs and supplies. This brings us to the dominant aspect of the problem of the world's wheat supply year by year. What aggregate surplus will be available from countries which produce more food than they need? What will the needs of the over-populated industrial centres be? Will the surplus of the one meet the needs of the other?

The international position is reviewed in tabular form week by week in the Tuesday issue of Broomhall's *Corn Trade News*. This sets the estimated surpluses of the exporters in producing countries against the estimated purchases of importers in consuming countries for the whole cereal year, and shows to what extent the programme of shipments has been realized up to the date of the issue. Such a summary for 8 December 1925 is given herewith:

Summary of International Wheat Position. Estimates for Season.

1 August, 1925, to 31 July, 1926.

Importers' Estimated Purchases.	*Estimated Season's Total.*	*Shipments to date (18 weeks).*	*Difference.*
	Qrs.	*Qrs.*	*Qrs.*
Europe	67,000,000	22,250,000	44,750,000
Ex-Europe (direct shipment)	15,000,000	5,500,000	9,500,000
Totals	82,000,000	27,750,000	54,250,000

Exporters' Estimated Surpluses and Probable Shipments.	*Total available Surplus.*	*Estimated Exports during Season.*	*Shipments Reported to date.*	*Remainder.*
	Qrs.	*Qrs.*	*Qrs.*	*Qrs.*
U.S.A.	10,000,000	8,000,000	19,500,000	23,500,000
Canada	35,000,000	35,000,000		
Argentina	21,000,000	17,000,000	2,450,000	14,550,000
Australia	11,000,000	10,000,000	1,350,000	8,650,000
Russia	5,000,000	3,000,000	1,450,000	1,550,000
India	1,000,000	1,000,000	200,000	800,000
Danube and Hungary	10,000,000	5,000,000	1,250,000	3,750,000
North Africa, Chile, &c.	3,000,000	3,000,000	1,550,000	1,450,000
Total	96,000,000	82,000,000	27,750,000	54,250,000

From this summary it will be seen that on an average 1,600,000 quarters of wheat are shipped from the exporting countries weekly (out of which half a million is destined for Great Britain, as we have seen). A striking figure is the small margin between the estimated needs (82 million quarters from the above statement)—based on the harvest figures of the importing countries, their population, and their consumption per head—and the surplus estimated to become available during the year to supply them (96,000,000 quarters). Now the total production of the countries included in the above international summary amounts to 370 million quarters. The margin of 14 millions is, therefore, on a production of 370 million quarters. This rather narrow margin is apt to provoke a doubt as to whether the close adjustment of world supplies to world needs is attained out of strength or weakness. Is a wheat famine close on our heels, or have the world's farmers, guided by price, gauged production automatically to meet needs, and would they be capable of increasing the wheat supply to any reasonable extent? The opinion with regard to this question has changed profoundly during the past decade.

It is now twenty-nine years since Sir William Crookes directed the attention of the scientific world to the narrow margin which appeared to separate us from famine. In a presidential address to the British Association in 1898 Crookes endeavoured to answer the above query as to the capacity of the world's farmers to feed the increasing population of the world.

Assuming the population of the white races to continue to increase at the same rate as they had increased in the decade before his address, and estimating the additional available wheat lands on the best available data, he forecast 1938 as the date when the surplus must disappear.[1]

Where Crookes looked to see this disastrous prospect relieved was in improvement in the yield per acre in the wheat lands of wheat-exporting countries. The average yield per acre in the United States is only about 14 bushels, compared with 32 bushels in England. Raising the yield is (to the extent that it does not depend on uncontrollable climatic conditions) within the power of the farmer by the use of nitrogenous fertilizers. No one could say in 1898 where such fertilizers would come from on

[1] Sir William Crookes, *The Wheat Problem*. London, 1899 and 1917.

a scale needed to supply the vast fields of wheat cultivated without them. The existing nitrogenous minerals in the earth are a fast-diminishing asset. Crookes urged the leaders of chemical industry to devote their efforts towards synthesizing the necessary fertilizer from the nitrogen of the air. The appeal was not unavailing, and the production of nitrogenous manures artificially is to-day a firmly established industry.

Opinion with regard to the ultimate future supply of wheat has changed not so much on this account as because of the present-day knowledge that the untouched areas available for wheat growing have proved to be much larger than was then suspected, so that even with methods of husbandry unaltered, supplies are certainly assured for a long time ahead.

This was illustrated in a practical way when supplies from Russia, which amounted annually to 20 million quarters before the war, ceased; her place was taken automatically by North America.

The stimulus of war prices increased the acreage put down to wheat in Canada from the pre-war five-year average of 9,945,000 acres to 19,118,000 acres in 1919, and in the United States from the pre-war five-year average of 50,802,000 acres to the 1919 figure of 76,683,000 acres. Smaller increases occurred in the Argentine and in Australia from the same cause.

Opinion is now inclined to err in the direction of over-confidence in the possibility of future production from increased acreage. It is true that Sir William Crookes anticipated no greater extension in Canada by 1923 than to 12 million acres, when in fact the acreage that year was 22·8 million. But often the potential wheat area of Canada is stated in fantastic figures. Careful inquiry[1] puts the maximum potential area at 80 million acres, and this figure is of the nature of a future limit and not one representing the immediate possible increase in acreage.

The human factor. The ultimate consideration is the human one of the minimum income which will induce the farmer to grow wheat on the edge of production in each country. What return will compensate the Canadian farmer[2] in facing the

[1] See C. P. Wright, *Wheat Studies: Canada as a producer and exporter of Wheat.* Stanford University, California, 1925.

[2] G. Bingham, *The Canadian Farmers' Economic Position.* Lecture at the City of London College, October 1925.

rigours of the Canadian climate on the edge of the wheat-producing areas? As present-day charges stand, when the price of wheat in London is 48*s.* per quarter the Canadian farmer's share amounts to 33*s.* With a yield of 16 bushels to the acre he can count on a net income of £280 a year from a 320-acre farm (allowing one-third of this area for fallow) after paying his mortgage, maintaining his farm machinery, hiring necessary labour, and paying for the threshing of his crop, and this figure includes of course recognition of his own labour at 5·00 dollars a day for 250 days. The difference between the 33*s.* the farmer gets in such a year and the 48*s.* the miller pays represents the absolute minimum cost of getting the crop marketed and moved, and competition is keen, the organization of the trade good, and publicity great, so that all competent men agree that no conceivable reduction is possible here. Consequently, the farmer feels immediately the effect of falling world prices, and it is this figure which determines the rate of expansion or contraction of the acreage of wheat lands in Canada, and incidentally of course in other countries. Inevitably the movement towards monopolistic control of the crops by the farmers themselves will gain ground in order that they may, in the form of 'pools', secure as high a return for their wheat as possible.

III

PRODUCTION OF WHEAT IN THE CHIEF EXPORTING COUNTRIES

THE countries from which the dense populations of Western Europe buy 95 per cent. of their overseas wheat requirements are Canada, the United States, Argentine, Australia, and India. These countries are given in the order of the extent of their net export of wheat and flour averaged over the five years 1920–4. The following table[1] expresses their acreage under wheat, production, yield per acre, and net export.

		Canada.	*United States.*	*Argentine.*	*Australia.*	*India.*
Acreage (million acres)	1909–13	9·9	47·1	16·1	7·6	29·2
	1920–4	21·7	60·2	16·0	9·8	29·1
	1925	22·0	52·2	19·2	10·8	31·8
Production (million bushels)	1909–13	197	690	147	90	352
	1920–4	340	837	198	135	346
	1925	417	670	215	116	328
Yield per acre (bushels)	1909–13	19·6	14·6	9·1	11·9	12·0
	1920–4	15·6	13·9	12·4	13·9	11·9
	1925	19·0	12·8	11·2	10·8	10·3
Net export (million bushels)	1909–13	96	110	85	55	50
	1920–4	234	231	126	91	17
	1925	220	86	105	98	20

Conditions of growth.[2] The main natural conditions which govern the successful production of wheat are a suitable soil, adequate rainfall at the right period of development of the plant, suitable temperature conditions, sufficient sunlight, and a sufficiently long period before early autumn frosts.

Wheat prospers best in heavy loams, the yield falling off in lighter sandy soils on the one hand or in heavy clays on the other.

The rainfall necessary varies considerably with the variety. Thus Durum wheat yields fairly with as low a rainfall as 12 in.

[1] C. P. Wright, loc. cit.

[2] *The Wheat-Plant*, John Percival, 1921.

per annum. The rainfall in the districts of eastern England where yields are heavy averages 22 in. Wheat is a deep-rooting plant and in consequence it can stand a long drought better than most other crops. Thus in England the wheat-producing counties are the driest ones. The period of development of the plant at which rain falls is of great importance. For winter wheat heavy autumn rains prior to seeding wash out the nitrates from the soil and this prejudices the crop from the start. Rain during the spring when the plant is making vigorous growth is very beneficial. From the time of escape of the ear until harvest rain is practically unwanted.

Winter and Spring wheat. The wheats of the world fall into two divisions: Winter and Spring wheats. Winter wheat is sown before winter sets in. The young plantlet is hardy enough to withstand the frosts of a winter in temperate countries and develops a good root system by the early spring. Spring wheats on the other hand are more delicate plants and would be killed by winter frosts if these were severe. They are sown in spring, grow fast, and are ripe about the same time as winter wheats.

Winter wheats thus have a long growing period amounting in extreme cases to 225 days, whereas spring wheats may run through the life cycle in as short a period as ninety days. The advantage of heavier yield is almost always on the side of the plant with the longer period of growth, and in consequence in those countries where spring wheats must be grown on account of the severity of winter weather, yields are invariably lower.

For the most successful cultivation of wheat a period of about fifty days of fine warm weather with an average temperature of 66° F. is necessary.

Wheats are referred to as early, mid-season, or late varieties, according to the average date at which they ripen. In England the ear escapes from the sheathing leaf of early varieties between the 14th and 24th May; of mid-season varieties between the 1st and 7th June; and of late varieties between the second week and last week in June. They ripen between eight and nine weeks later.

Colour of wheat. A character of the grain which concerns the grain trade is its colour. Wheats are classed as Red or White, and the justification of this designation is perhaps best realized when a considerable bulk of a typical white or red

wheat can be seen, as in the hold of a vessel. In fact the colour varies through all shades of creamy white to orange red. The colour of the wheat in small samples must be judged under a window facing north, against a dark background, or by using an artificial-daylight lamp.

The colour of wheat is due to three interacting factors: (*a*) the colour of the seed-coat seen through (*b*) the transparent colourless pericarp against (*c*) the mealy or flinty endosperm. The pericarp or skin of the grain is almost colourless. It may be carefully peeled off a red wheat and held up to the light, when it will be observed to be practically without colour. The thin seed-coat which lies beneath the pericarp is pigmented and gives the tone to the grain. The endosperm, however, is not without its effect on the external appearance of the grain. It may be very white and floury as in English wheat (say Standard Red) or in Soft Red Winter. The grain then has a *light* orange-yellow colour. Or it may be flinty, as in Yeoman or Manitoba (red wheats), when the appearance of the grain is considerably darker. On the other hand, a white wheat with floury endosperm, such as Pacific White wheat or Soft Australian, appears very light yellow, while Durum, which has a flinty endosperm, appears wax-like or amber coloured.

Wheat in Canada.

The wheat lands of Canada are practically confined to the prairie provinces of Manitoba, Saskatchewan, and Alberta, comprising an area of 20–22 million acres, extending about 800 miles from east to west and 300 miles from the frontier northwards. They form a northern continuation of the wheat lands of Minnesota, North Dakota, and Montana. Extensive as this area seems, it nevertheless represents only one-quarter of the distance across the continent from Halifax to Vancouver. From Winnipeg westward the prairie lands fall into three natural regions or steppes. The most easterly is in Manitoba at an elevation of 750–800 ft. above sea-level. The central district (Saskatchewan) lies at an elevation of 1,600 ft., and the western steppe at 2,800 ft. elevation stretching to the Rockies, comprises the province of Alberta.

The rich loamy soil of this area is admirably adapted to wheat growing, and the lack of primeval forests made it possible to bring virgin land under the plough without the necessity of clearing. Rain falls during the growing season, and the quality of the wheat grown is not excelled anywhere in the world.

Difficulties of cultivation. The natural hindrances to cultivation and marketing the crop are nevertheless many, and although the latter have been surmounted the former must remain. In the first place the growing season is narrowly prescribed by climatic conditions. From November till March the soil is frozen hard to a considerable depth, and by the end of August the frosts return again. In Saskatchewan only 114 days elapse between the average date of sowing in April to the average date of the first frosts of late August. Nearer Winnipeg the time is extended to 145 days. Thus, damage from late frost (in May) threatens the young crop at the outset of its life, and from early frosts (in August) as it is approaching harvest, and this danger is very real.

Although the rain falls in the critical months it is less in quantity than in the driest parts of eastern England. It averages only 15 in., while the average for East Anglia is 21 in. Thus, it is often the limiting factor to the yield, and in some years, and in some districts, the effects of drought are disastrous. The July rainfall is the critical figure. Again, local summer hailstorms may often do great damage to the crops of individual farmers, and rust may take a great toll of the ripening harvest. Normally, only wheat is grown, and this fact alone raises serious problems of husbandry, the chief being that it leads to a rapid exhaustion in the fertility of the soil. The practice of leaving one-third of the farm fallow for one year while the other two are sown to wheat gives the land the only chance it gets of regeneration. In consequence, the yield per acre in Canada has gradually fallen, as the figures in the above table indicate. Exclusive wheat farming also makes it difficult to clean the land, with the consequence that weeds are a serious trouble.

With the capricious operation of so many hindering factors it is not surprising that although the prairie provinces of Canada are suited in the highest degree to wheat growing, the crop of Canada should vary enormously year by year. And this is indeed the case, as the magnificent crop of 1923 (474 million

bushels), followed by the disastrous one of 1924 (262 million bushels), indicate.

Crop reports are published by the Canadian Dominion Bureau of Statistics, and independent reports by the Winnipeg Free Press and the North West Grain Dealers' Association.

Only one-third of the crop is needed for home consumption and for seed, since the population is only 9 millions, so that the wheat is grown mainly for export. The tale of the development of the Dominion wheat lands is consequently that of the development of her means of transportation, for Winnipeg is 1,500 miles from the seaboard and the Rockies intervene between the wheat lands of Alberta and Vancouver. Thirty years ago the export of wheat from Canada was about 10 million bushels, whereas in 1923–4 it was 348 million. The farm lands are admirably served by the Canadian Pacific and the Canadian National Railways.

Transport. Eastwards the grain moves in great volume during September, October, and November towards Winnipeg, where it is graded, and thence 400 miles farther to Fort William and Port Arthur, at the head of Lake Superior, which together have a storage capacity of 64 million bushels. From this strategic centre it is shipped by one of five routes[1] to the seaboard and thence to Europe. On or near the 15th December the lakes and the St. Lawrence freeze up, so that until the great thaw at the end of April the only delivery possible is by rail to the United States seaboard.

Since the opening in 1914 of the Panama Canal grain has been shipped in increasing quantities through Calgary or Edmonton,

[1] These routes from Fort William and Port Arthur are as follows:

(1) Via the Great Lakes to Buffalo: thence by rail to New York, Philadelphia, Baltimore, and Boston. Volume handled, 80–100 million bushels.

(2) Via the Great Lakes and the Welland Canal to Montreal. 40-5 million bushels handled.

(3) To Port McNicoll and Midland Tiffin on Georgian Bay, Lake Huron: thence by rail to Montreal or the seaboard. 15–20 million bushels handled.

(4) To Goderich on Lake Huron for supply to mills in SE. Ontario, 10–15 million bushels handled.

(5) By rail from Fort William and Port Arthur. 10–20 million bushels handled. (C. P. Wright, loc. cit.).

where it is graded, to Vancouver and thence through the Panama Canal to Europe or to the East.

The kind of wheat grown practically over the whole of Manitoba, Saskatchewan, and Alberta is that known commercially as Northern Manitoba wheat. The varieties grown are Marquis and Red Fife. Northern Manitoba wheat sets the world's standard of milling quality on account of its 'strength'. A small quantity of winter wheat, however, is raised in Alberta.

Wheat in the United States of America.

The United States heads the list of the world's producers of wheat with a total acreage in 1925 of 52·2 million acres and a crop of 670 million bushels. This was a poor year. In the previous year the crop, on a very similar acreage, had amounted to 863 million bushels. (The production of Russia in 1913, viz. 880 million bushels, slightly exceeded this figure.) But the yield is low, amounting only to about 14 bushels per acre. This is to be explained by the extensive size of the farms, by the practice of continuous wheat production, the limiting climatic conditions over considerable areas under wheat, and the small amount of fertilizers used.

Hard Red Spring wheat is raised over an area of about 14 million acres, or about 25 per cent. of the total wheat lands of America. The area devoted to this crop, viz. North and South Dakota and Minnesota, running through the great milling centre of Minneapolis, is a southern continuation of the western Canadian prairies where the climate is similar. The winters are too severe for autumn-sown wheat. The rainfall is between 15 and 35 in., and falls mainly during the growing season. This wheat, like that of the prairie provinces of Canada, which is of the same variety, is unexcelled in the world. The spring wheats of the middle Volga districts of Russia are similar. The limits of the area devoted to spring wheat are determined by the rigours of the winter, for where winter wheat can be grown its yields are naturally higher and it is preferred.

Durum wheat has been found suitable to the drier parts of this same region and its cultivation since its introduction in 1905 as a spring crop has steadily increased. It is also rust resistant. About 3½ million acres are devoted to this variety,

forming about $6\frac{1}{2}$ per cent. of the wheat acreage. It is used, in the form of Durum semolina, in the manufacture of macaroni. About half the crop is exported, and is beginning to be largely used for bread making.

The most extensive wheat area is occupied by Hard Red Winter, a wheat which yields well, resists drought, is winter hardy, and produces good bread. Hard Red Winter wheat is grown south of the northern spring area in the plains of Nebraska, Kansas, and Oklahoma, where the summers are hot and the rainfall, towards the western parts, as low as 18 in., rising eastwards to 35 in. The acreage devoted to this class of wheat is larger than that of any other, amounting to about 32 per cent. of the total. June is the chief harvest month. The main grain centres in this district are Kansas City and Omaha. The quality of this wheat is similar though slightly inferior to that raised in South Russia, between the sea of Azov and the Caspian, including the Crimea.

Soft Red Winter wheat is adapted to the more humid and milder climate of the eastern states, where the rainfall is between 30 and 40 in. Missouri, Indiana, Ohio, and Illinois lead in the cultivation of this class of wheat. The acreage is round about 20 millions and accounts for about 30 per cent. of the total wheat area. Seed-time is in September or October and the principal harvest month July. The densely populated towns of Milwaukee, Detroit, Cincinnati, Chicago, Cleveland, Dayton, and Indianapolis, which lie in this region, consume a large part of the crop. The transport facilities within the area both by rail and lake are excellent. Flour from Red Winter wheat is not suitable alone for bread making on account of its lack of strength.

White Winter and Club wheats occupy together about 7 per cent. of the total acreage, mainly in the Pacific area in Oregon, Washington, and the Sacramento Valley. They are of excellent colour and well suited to the manufacture of pastry, flour, biscuit, and breakfast foods.

The Argentine.

The Argentine ranks third as a supplier of wheat to Europe. In the period 1900 to 1920 the export of wheat and flour

increased from 60 million bushels (the average of 1900–2) to 134 million bushels (the average of 1920–3), and the possibilities for expansion are very considerable.

Wheat is grown over an area extending from Cordoba in the north to Chubut in the south, a distance of 900 miles. The kind of wheat, the harvest time, and the incidence of the season on the crop vary with the district, as would be expected in an area reaching over 12 degrees of latitude from north to south. In the north, in Santa Fe, seed-time is in May and this gets later as the more temperate regions are reached farther south, until in Chubut wheat is sown in August. The harvest shows a similar sequence, beginning with Sante Fe wheat in mid-November and extending into mid-January in the south.

The wheats in cultivation are of southern European origin. Barletta wheat, a red wheat from Italy, has proved to be very well suited to the climate and soil of the districts west and south of Buenos Aires. It resembles American Hard Winter wheat, but is not so hard. Russian wheat is also largely grown. These varieties give bigger yields of harder grain in the colder and drier southern districts. Among the natural causes of damage to grain crops in the Argentine the following may be mentioned: black rust, high winds causing the grain to shell out, floods, and locust.

For export purposes the distinction is drawn between Barletta and/or Russo wheat when shipped from Bahia Blanca (i. e. grown in the southern districts) and wheat of the same varieties shipped from Buenos Aires (i. e. grown in the districts west of Buenos Aires). To the former, viz. Barletta and/or Russo wheat shipped from Bahia Blanca, the trade designation of Barusso wheat is assigned. To the latter, viz. Barletta and/or Russo wheat shipped from Buenos Aires, the trade name Baril is given.

Besides these two descriptions there comes Rosafe wheat, grown in the province of Santa Fe and shipped from the river ports of Rosario and San Lorenzo. Lastly, on the eastern side of the Parana the province of Entre Rios produces a wheat peculiar to itself. A small quantity of Durum wheat is grown for home consumption. Except in Buenos Aires elevators are not used, and vessels are loaded directly from railroad wagons. Plate wheats possess sufficient strength to make a satisfactory loaf when milled alone.

IV

AUSTRALIA, INDIA, AND RUSSIA

AUSTRALIA.[1]

THE wheat of Australia is characterized commercially by its uniformity, its magnificent cream colour, and its mature condition.

Acreage. An area of 10 million acres is devoted to its production, divided between the respective states as follows: New South Wales, 3 million acres; Victoria, 2·7 million; South Australia, 2·5 million; West Australia, 1·6 million; Queensland, 0·1 million.

Production. The production has averaged 135 million bushels during the five-year period 1920–4, which represents an average yield per acre of 13·9 bushels.

Consumption. The population is 5,437,000 and the home consumption may be put at 30 million bushels. The average net export has amounted to 87 million bushels over the period named. This includes a considerable export of flour amounting in 1924 to 380,000 tons or say, the equivalent of 19 million bushels.

Cultivation. An early governmental report on the rusts of Australia indicates that that trouble was at one time very severe. But this was before the cultivation of land on the continental side of the coastal mountains. The coastal plains of New South Wales, which were the first to be settled, have a rainfall of 30 to 40 in., and there wheat growing proved unsuccessful. The wheat areas of to-day lie inland from the mountain ranges and extend into the Mallee Scrub. The rainfall in the best districts varies from 25 in. down to 10 in. and in the Mallee country from 16 in. to 10 in. Seeding takes place in May and June and the harvest in November and December, when the grain is dead ripe, so that

[1] C. T. McGlew, *The Grain Trade of Australia*, City of London College Grain Trade Lecture, No. 8, 1925.

it may be reaped, thrashed, and sacked by the header harvester. The size of the crop depends in the main on rain falling during May and June and in August, September, and October.

The grain is bagged and sold either to the Wheat Pool of the particular state or to merchant firms. It is railed to the ports of the respective states, the chief of which are Sydney for New South Wales, where storage in silos is available and the grain is handled in bulk, or Melbourne for Victoria, Adelaide for South Australia, and Freemantle for West Australia, where it is stored in bags. If it is sold to the Pool the farmer receives a receipt for his wheat and an advance at a fixed price per bushel for his delivery. Then when the wheat is disposed of at the end of the season he receives an additional sum adjusting the price per unit he receives to the average realized by the Pool. This is the method of co-operative selling. The new crop wheat arrives in Europe in February.

The limits to the possible future acreage of wheat lands in Australia have never been fixed. The Government statistician places it at as high a figure as is given officially for the ultimate acreage possible in Canada. It is at any rate certain that wheat growing in Australia has an immense future. Methods for cultivating areas under Mallee, a bush of 10 to 12 ft. in height growing in light soil, have been extremely successful and the presence of artesian water proved over a vast area of 600,000 square miles.

INDIA.[1]

With an annual production of 350 million bushels, India ranks as the world's second largest producer of wheat, but on account of her immense population of 300 millions not more than 10 per cent. of the crop is available for export.

Areas of production. Wheat is grown mainly in northern India. In the Punjab it is grown on irrigated land, the crop amounting to 140 million bushels, from which 70 per cent. of the export is derived. The United Provinces grow the next largest crop, but this is more dependent on winter rains and is consequently variable.

[1] H. J. Casey, *The Indian Grain Trade*, City of London College Grain Trade Lectures, No. 9, 1924.

The acreage under wheat has been constant for many years and is not likely to be increased unless the completion of the Sukkur barrage should bring irrigated land in Sind under wheat. The yield per acre averages twelve bushels, so that any increase in the quantity available for export must come from increased yield. Seed-time for wheat, barley, and gram is October and November and the crop is reaped in March and April. The amount of wheat available for export is largely dependent on the crops of millet (juár), *Sorghum vulgare,* and spiked millet (bájra), *Pennisetum typhoideum,* which form the staple food of the people. These grains are sown in June to July and harvested in September to October. If this crop is short, it inevitably reduces the quantity of wheat and barley available for export. Moreover, the consumption of wheat *per capita* is on the increase in India.

Wheat for export is railed down by the North Western Railway to Karachi or its port Kiamari, where it is stored in exporters' go-downs or, when these are full, in the open air. For shipment, each lot is weighed and analysed for dirt and foreign seeds. It is then bulked with other lots similarly handled and resacked at even weights of two cwt. net.

Storage. Weighed stocks of grain [1] are stored in bulk in the Punjab in square brick buildings known as kothas. Grain is poured into the kotha until it is full and is then bricked over. When it is required, the brick roof is removed, the layer of weevil and frass which has accumulated at the top of the bulk is scooped off, and the rest of the grain sacked and railed in good condition.

In the United Provinces grain is stored in huge circular pits which taper to a bottle neck. After being lined with straw, grain is poured in and they are sealed up. Grain stored in such pits acquires after a time a musty smell which is difficult to remove.

Commercial varieties. The chief commercial classes of Indian wheat are as follows:

(*a*) Choice White Karachi, constituting fully 90 per cent. of the total wheat exported. This consists of a mixture of

[1] The native unit of weight is the maund of 82 lb. 8 maunds are equivalent to 1 khandi (or 656 lb.).

75 to 80 per cent. white and 20 to 25 per cent. red wheat, derived from the Punjab, the United Provinces, and Sind.

(b) Soft Red Karachi. A flowery red-skinned wheat—apparently hard on account of its dryness. It is like the red grain in the above-named white class.

(c) Choice White Delhi, Choice White Bombay, and Bombay Club. Small quantities only are shipped of each of these classes. They are bold white wheats with a fair proportion of red admixture. They rank with Australian and Soft White Pacific wheat.

Indian wheat has a characteristic dull mat appearance on the surface. The individual grains are frequently very large. Red and white varieties invariably occur mixed. The grain is very dry, averaging 10 per cent. moisture. It is shipped dirty and sold on 'clean' terms; that is, the seller makes an allowance to the buyer in accordance with a scale laid down by the London Corn Trade Association for the amount of admixture of dirt and non-farinaceous seed and for farinaceous seed other than wheat in the shipment in excess of 2 per cent. The contract specifies that up to 2 per cent. of such farinaceous seed is to be taken and paid for as wheat. This involves careful and comprehensive sampling at the port of discharge and determination in London of the quantity of admixture from the sample so secured.[1] The allowance is then made on the result of the analysis. This recognition of the presence of admixture in Indian grain has been held, and perhaps rightly, to remove incentive towards shipping grain from India in a clean condition.

Russia.

Production. In 1913 Russia headed the list of wheat-producing countries with a production of 880 million bushels, 122 million bushels of which were exported. In 1924 the production was 333 million bushels; in 1925, 576 million, and the estimate for 1926 is slightly larger. Exports of wheat from Russia in the cereal years 1923–4 amounted to 23·2 million bushels; in 1924–5 only 320 thousand bushels, and in 1925–6, 30·4 million

[1] *The Work of the London Corn Trade Association*, S. H. Titford, City of London College Grain Trade Lectures, No. 3, 1925.

bushels. Rye, however, is the dominant cereal crop and the chief food of the people, a large part of the wheat crop being for export.

Wheat is grown mainly in South Russia in the middle and lower Volga, in the Ukraine, in the districts round the Crimea, and between the Black Sea and the Caspian. The following provinces lead in production: Don, Orenburg, Taurida, Samara; and Ekaterinoslav, Kiev, Podolia, and Poltava in the Ukraine.

Soil and Climate. The soil in these districts is of unsurpassed fertility. They lie in what is known as the Black Earth Zone, the soil containing from 4 to 16 per cent. of organic matter which produces luxuriant plant growth with very little husbandry.

The northern limit of the Black Earth district runs in a north-east south-west direction from Ekaterinburg east of the Volga to Volhynia by the Carpathians. Its southern limit is not so well defined. It runs along the north-west shores of the Black Sea to the Caspian, including part of the Caucasus. It thus embraces the provinces named above and forms an area of a quarter of a million square miles. It is watered by the Don, the Dnieper, and the Volga.

The precipitation is low and sets the limit to yield. It rarely exceeds 22 in. and is mostly in the form of snow. In Orenburg it averages 15·6 in., in Kharkov 19·4, and towards the south-east it falls so low as to form arid steppes uninhabitable except for nomadic races, in spite of the excellent soil. In Astrakan the precipitation averages 6 in. only. Thus the size of the crop is particularly difficult to forecast from the acreage. It depends very largely on the depth of snow cover in winter. When the spring thaw arrives the soil gets its only thorough drenching.

The temperature extremes between midsummer and midwinter are very great, so that, except in districts where snow lies thick in winter, spring wheat is the rule. The area under winter wheat, mainly in the Kiev district, is less than one-third of the total.

The yields are low, partly on account of the small rainfall, but also on account of the undeveloped methods of agriculture. The average yield of winter wheat in pre-war days was 9·6 and of spring wheat 6·4 bushels per acre.

The harvest takes place in July in the South and in September and October in North Russia. The average export from Russia

to the United Kingdom before the war was 22·6 million bushels. The recent export figures to this country are as follows: 1923–4, 1·7 million bushels; 1924–5, 2,400 bushels only; 1925–6, 2·4 million bushels.

The grain is sold to the United Kingdom on sample on London Corn Association Contracts, which contain an admixture clause, for the grain is not clean.[1]

Commercial varieties. The varieties of wheat exported vary greatly and for this reason the sale is on sample. From the Ukraine a flinty red wheat much mixed with rye is shipped to Black Sea ports. A softer wheat fairly free from rye is shipped from Theodosia. Wheat shipped from Leningrad is very hard, with a longer grain than Manitoba wheat, and containing frosted grain, wild oats, and cockle.

The ports of shipment are Novorossisk, Odessa, Nikolaiev, and Theodosia on the Black Sea, and Leningrad on the Gulf of Finland. These ports are closed by ice during the winter. Thus Leningrad is open 218 days, Nikolaiev 280 days, and Odessa 288 days in the year.

[1] The Soviet Government has drawn up grading and inspection rules and has issued a grading certificate. It appears to be based on the American model.

V

BOTANY OF THE CEREALS

THE Gramineae or grass family provide mankind with a wide range of valuable crops. The chief of these are grouped together as the cereals, viz. wheat, rye, barley, oats, maize, rice, sorghum, and millet. Wild forms of wheat, oats, barley, and rye are well known, and from these our cultivated cereals may be presumed to have been derived by persistent care through many centuries. As recently as 1906 a wild wheat was discovered in Palestine, although it is not considered to be the direct progenitor of the commonly cultivated bread wheats.

The 'Ear' or Inflorescence. A character common to all the cereals is the dry, hard seed and its coverings, known as the grain. The grains are borne in a definite and orderly manner on the stem. In wheat, barley, and rye the upper part of the stem is flattened and notched to accommodate them as in A, Fig. 2. This part of the stem forms the axis of the ear and is known as the rachis. Each grain develops from an inconspicuous flower referred to as a floret. The florets may be single or grouped together in twos or threes forming a spikelet; such a group of three florets forming a single spikelet as in wheat is shown in B, Fig. 2. The spikelets are borne on alternate sides of the rachis on the notches already described, the whole series thus forming the ear or inflorescence. Each floret has two thin coverings called respectively the inferior and superior palea. The ripened grain falls freely away from the paleae in wheat and rye, but in oats and barley they remain attached to the grain, forming the husks. The inferior palea sometimes forms an outgrowth which may be many inches in length, known as the beard or 'awn'. This is shown in C, Fig. 2, barley. All the florets within one spikelet are embraced by a pair of chaff-like leaves called glumes.

Structural characters of the cereals. In the genus *triticum*, wheat, each notch of the rachis bears one spikelet of three or

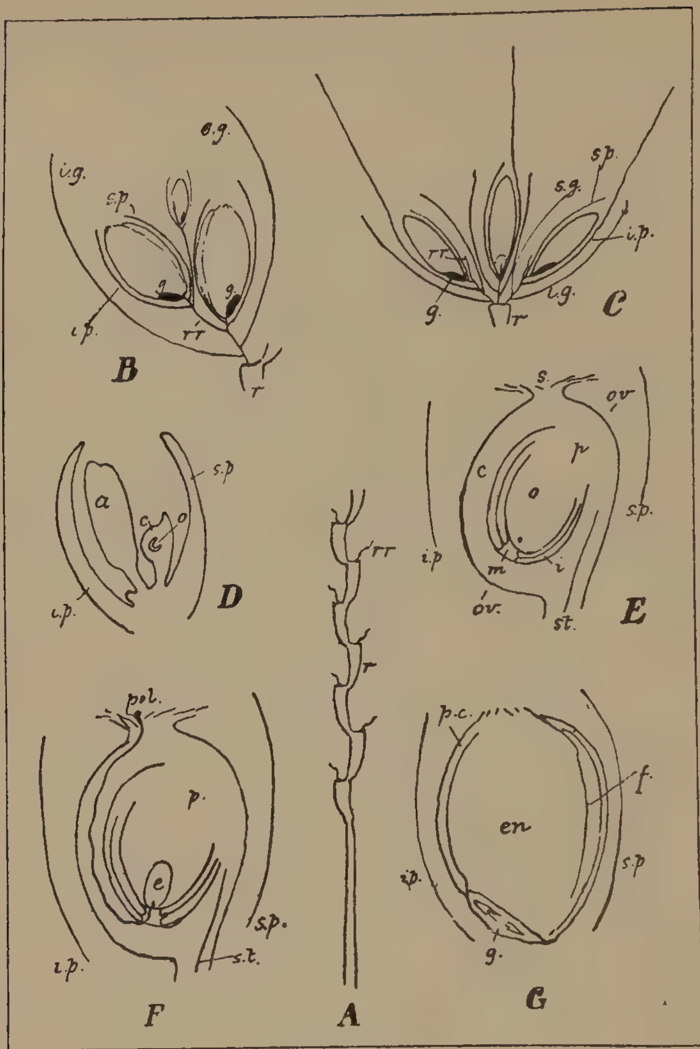

Fig. 2.

A. Axis of infloresence of wheat: *r*, rachis; *rr*, rachilla.

B. Diagram showing single spikelet of three florets, as in wheat or oats: *i.g.*, inferior glume; *i.p.*, inferior palea; *s.g.*, superior glume; *s.p.*, superior palea.

C. Diagram showing three spikelets of one floret each, as in barley.

D–G. Diagrams illustrating the development of the grain of wheat from the flower: *a*, anther; *c*, carpel; *e*, embryo sac; *en*, endosperm; *f*, furrow; *g*, embryo or germ; *i*, integument; *m*, micropyle; *o*, ovule; *ov*, ovary; *p*, placenta; *p.c.*, pericarp; *pol*, pollen grain; *s*, stigma; *st*, conducting strand.

more florets, the uppermost floret usually being reduced in size and empty.

In the genus *hordeum*, barley, each notch bears usually three spikelets containing one floret each. The lateral spikelets may be reduced in size, sterile, or, in some cases, absent altogether.

In the genus *avena*, oats, the spikelet is two-flowered or more, but it is borne on a thin pedicel, the whole inflorescence forming a loose head or panicle.

In the genus *secale*, rye, each notch bears a single spikelet of two flowers. The glumes in rye are long, narrow, and pointed.

In the genus *zea*, maize, each plant bears separate male and female flowers. The female flowers are borne on a spike which ripens to form the cob.

Development of the Grain. Diagrams D, E, F, G, in Fig. 2, illustrate the progressive development of a single grain of wheat, from its inception as a floret up to its maturity. The floret is made up of an ovary containing a single ovule which ripens to a single grain, surrounded by three anthers containing pollen and enclosed in two chaff-like paleae. D shows a highly magnified section through an immature floret, passing through the paleae, one of three anthers and the ovary. The ovary consists of a carpel enclosing a single ovule. The ovule (diagram E) is attached to the inner wall of the carpel by its broad base, not in an upright position, but inverted, and this accounts for the position of the ripened grain within the chaff. The area of the carpel to which the ovule is attached is known as the placenta.

Soon after the formation of the floret two enveloping coats made of simple cells may be seen growing round the central portion of the ovule, but leaving a minute opening known as the micropyle. The enveloping coats are known as the integuments. Opposite the micropyle, one well marked cell with a large nucleus can be distinguished. This single cell is destined to become germ, endosperm, and aleuron layer in the ripe grain. It is called the archesporial cell, and is marked in the diagram by a black dot. It grows by absorbing the adjacent tissue until it forms one large cell known as the embryo-sac, containing the ovum, or female gamete (F, Fig. 2). The ovum is fertilized by the growth of the pollen which is shed by the surrounding anthers on to the feathery receptive surface at the top of the

ovary, known as the stigma. The anthers are borne on long slender filaments, and after the liberation of the pollen they shrivel and disappear. Thus the anther is absent at the stage represented by diagram E. At flowering time the anthers may be seen protruding from the chaff on the ear. F illustrates the growth of a pollen grain, each of which consists of a single cell, into a long tube which penetrates the ovary wall and the micropyle to the ovum. The pollen tube conveys the male gamete derived from the nucleus of the pollen grain to the ovum, where the gametes fuse. The contents of the embryo-sac now become very active in growth. The fertilized ovum develops into the embryo, or germ (diagram G), which remains comparatively small, while the remainder of the embryo-sac develops fast by absorbing the surrounding tissue until it occupies the whole of the space within the integument, forming thus the endosperm. To supply the needs of the rapidly developing seed, soluble carbohydrates are brought up by the sap from the leaves and stem of the plant. This food enters the grain by a conducting strand in the carpel wall, and diffuses into the developing cheeks of the grain from the furrow, where the conducting strand is situated. Here it is stored in the form of starch. At the milk stage the fruit is plumpest and contains most moisture. As it ripens it dries out and becomes smaller and harder. It also becomes detached from the rachilla which bears it and lies free within the paleae or chaff.

Nature of the grain. We see, therefore, that the fruit of the wheat flower consists of a dry, thin pericarp (the outer covering of the ripened ovary) closely grown on to the seed, which is the name given to the ripened contents of the embryo-sac, namely, the germ, endosperm, and its immediate covering. To a fruit of this description the name grain or caryopsis is applied. Comparing it with a barcelona nut, the shell of the nut corresponds to the carpel wall of the grain. On cracking the nut, the seed falls out. To effect the corresponding separation in the grain the pericarp must be peeled off, for it grows tightly on to the seed.

We have next to examine a grain of wheat to trace its complex structures to their systematic position in the flower as we have described it.

Externally we see an oval-shaped grain bearing at one end

a number of fine hairs covering the slightly flattened tip of the grain. These hairs occupy the position of the stigmas. At the opposite end of the grain, on the rounded or dorsal side, lies the shrivelled embryo or germ. This is the product of the fertilization of the ovum. On the ventral side of the grain, running from tip to tip, is a deep furrow or crease. Where the furrow comes almost into contact with the germ the point of attachment of the grain (= ovary) to the rachilla may be seen. It is by this route that the food was brought into the ripening grain.

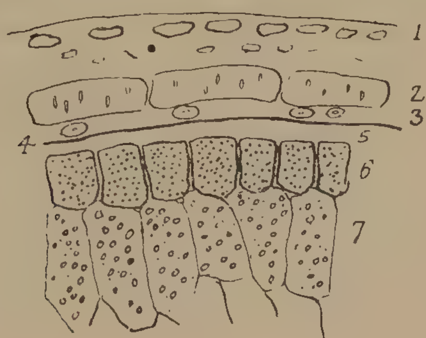

FIG. 3.

Diagram showing the structure of the pericarp and endosperm of a grain of wheat:

1. The epidermis, 2. The cross cells, 3. The tube cells — of the pericarp.
4. The testa.
5. The nucellar layer.
6. The aleuron cells.
7. The starchy parenchyma.

Microscopic structure of the grain. Sections taken along and across the grain show its six main structural features, namely (*a*) the pericarp, (*b*) the remains of the integuments now called the testa, (*c*) the remains of the epidermal cells of the tissue surrounding the embryo-sac known as the nucellar layer, (*d*) the aleuron layer, (*e*) the starchy parenchyma, and (*f*) the embryo or germ. These are illustrated in Fig. 3.

(*a*) The carpel wall, or pericarp, consists of four or five layers of cells together about 1/500th in. thick. The outermost layer, called the outer epidermis, runs lengthwise from the base to the tip of the grain, where its cells give rise to the hairs mentioned above. Beneath this layer come two ill-defined and crushed layers of simple tissue. Next follows a well-defined layer of cells called the cross-layer, which runs transversely round the grain. Succeeding the cross-layer comes the inner epidermis of

the pericarp, consisting of long tube-shaped cells which run parallel with those of the outer epidermis. These tube cells do not form a continuous tissue, but are separated from each other in the ripe grain. All these cells are empty and colourless in the ripened grain. To illustrate this, part of the pericarp may be peeled off a grain of Manitoba wheat, when it will be seen to be colourless and transparent on holding it to the light and viewing it with a hand lens.

(*b*) The testa or seed coat is conspicuous in a cross-section of a grain of red wheat, since it bears the pigment to which the colour of the grain is mainly due. It consists of the remains of the inner integument.

(*c*) Remains of the tissue surrounding the embryo-sac persist as a bright line immediately beneath the conspicuous testa. No cell walls can be easily distinguished.

(*d* and *e*) The endosperm consists of the starchy parenchyma (*e*) surrounded by a single layer of rather thick-walled cells known as the aleuron layer (*d*), except where the germ comes in contact with the starchy parenchyma. In section the aleuron cells appear square, in surface view polygonal. The aleuron layer is packed with granules containing protein, but not gluten. The starchy parenchyma of the endosperm consists of very thin-walled elongated cells the long axes of which point towards the centre of the grain. These cells are filled with innumerable starch granules embedded in a matrix of protein matter representing the protoplasmic content of the cell. It is from this protein that the gluten is derived when crushed and wetted. Without staining the section it is not possible to see the protein, but by staining with eosin or Congo red the protein is coloured, and by drying gradually in alcohol, dissolving the fat with xylol, and mounting the section in clove oil the starch granules are rendered invisible so that the stained protein stands out clearly. The cells immediately beneath the aleuron layer are richer in gluten than those in the centre of the endosperm.

The starch of cereals. The shape and size of the starch granules of the cereals are characteristic of each kind and are tabulated[1] below:

[1] Erdmann-König, *Warenkunde*, 15th edition.

	Size of Granules.	*Shape of Granules.*	*Other characters.*
Wheat starch	1. Large granules, 28–40 μ	Approximately circular or elliptical	
	2. Small granules, 6–8 μ	Approximately circular	Granules single and clear
Rye starch	1. Large granules, 35–50 μ	Approximately circular or elliptical	Concentric markings sometimes present and hilum noticeable
	2. Small granules, 6 μ	Approximately circular	
Barley starch	1. Large granules, 20–30 μ	Elliptical, kidney shaped or subangular	No concentric markings
	2. Small granules, 1–4·5 μ	Rounded or spindle shaped	Often in groups
Oats starch	1. Compound grain, individual granules measure 7 μ	Elliptical angular	Made up of as many as 80 angular grains
	2. Simple grains, 13 μ	Rounded	Single, clear
Maize starch	1. 6–25 μ	Angular and many sided	Present in the glassy endosperm
	2. 6–25 μ	Rounded	Present in the mealy endosperm No concentric rings in either but star-shaped hilum
Rice starch	Compound grains. Individual granules measure 3–10 μ	Angular	Containing up to 100 granules. No rounded grains

$\mu = 0{\cdot}001$ millimetre or approximately $\frac{1}{25,000}$ inch.

(*f*) The embryo or germ consists of the young wheat plant complete with root and shoot. The embryo is attached to the endosperm by a structure known as the scutellum. So much may be made out with a hand lens on a grain cut through with a razor. The scutellum presents a large convex area of tissue in contact with the endosperm. The surface cells are designed to effect the transference of the contents of the endosperm to the young plantlet when it germinates. The germ is very small, only accounting for from 2·8 to 3·5 per cent. by weight of the whole grain. It consists of very delicate cells highly differentiated as above mentioned into the root and shoot of the young plant and their protective sheaths. With care it may be detached intact from a softened grain. It is removed almost entirely from white flour in the process of milling. It contains about

half its weight of fat and in consequence is not reduced to powder in its passage through the rolls but is flattened into a disk-shaped object which is separated by sieves.

In wheat the embryo forms from 2·8 to 3·5 per cent. of the grain, the pericarp, seed coat and aleuron layer together form from 7·8 to 8·6 per cent., and the starchy endosperm from 87 to 89 per cent.

The structural features of the grain of other cereals are very similar to those of wheat.

(*a*) The structure of the rye grain is practically identical with that of wheat, differing only in minute characters.

(*b*) In barley the paleae are grown on to the grain (except in the 'naked' forms). The actual pericarp is very thin. The aleuron layer consists of two or three layers, becoming single near the embryo.

(*c*) In oats the epidermis of the pericarp consists of large cells, polygonal in shape, from which grow out very conspicuous hairs. The aleuron layer is single.

VI

BOTANICAL CLASSIFICATION OF WHEATS[1]

THE wheats of international commerce are derived from three cultivated species of the genus *triticum*. These are:

Triticum vulgare or Bread wheat;
Triticum durum or Durum wheat;
Triticum compactum or Club wheat.

Certain other species are cultivated in restricted areas, namely:

Triticum turgidum or Rivet or Poulard wheat;
Triticum Spelta or Dinkel or Large Spelt;
Triticum dicoccum or Emmer;
Triticum monococcum or Small Spelt, or Einkorn, or Engrain;
Triticum polonicum or Polish wheat.

Three other cultivated species are grown in very restricted areas:

Triticum orientale or Khorasan wheat;
Triticum sphaerococcum or Indian Dwarf wheat;
Triticum pyramidale or Egyptian Cone wheat.

Two wild species are known:

Triticum aegilopoides, Wild Small Spelt;
Triticum dicoccoides, Wild Emmer.

Wild Small Spelt is the progenitor of Small Spelt and Wild Emmer of Durum and Rivet. The wild form from which bread wheat and Club wheat were derived has not been discovered. In the wild wheats and in Small Spelt, Emmer, and Large Spelt the rachis breaks up on maturity and the spikelets attached to a piece of the rachis are scattered, the grain remaining tightly enclosed by the chaff.

Bread wheat (*T. vulgare*). This species produces flour most suitable for bread-making, and in consequence of its adaptability to a large range of climatic conditions some variety or other is grown in almost every country of the world. The number of such varieties exceeds 1,000. Some varieties are bearded and others beardless. The grain is plump, white or red, mealy or

[1] *The Wheat Plant,* John Percival, 1921.

flinty, strong or weak. Of the commercial classes mentioned on p. 42, all except Rivet of the home-grown wheat, Durum and Club wheats of America belong to this race of wheats.

Durum wheat (*T. durum*) is the next most extensively cultivated race of wheat. It is grown throughout the countries bordering on the Mediterranean, in the Black Earth district of Russia, in the United States (p. 22), Canada (where it is known as Goose wheat), and in small quantities in South America. The points in its favour are that it can resist a prolonged drought better than Bread wheat, and it is resistant to rust and smut. It is, however, susceptible to frost and is consequently a spring wheat.

Its grain is long, narrow, hard, more or less pointed at both ends, with a prominent dorsal ridge. Its endosperm is flinty and the colour of the grain amber to yellow. Its marked flintiness has stood in the way of its utilization as a milling wheat for flour until recently. It is mainly used for the manufacture of macaroni, for which purpose it is not milled to flour but to the semolina stage. Durum semolina is exported from the United States in considerable quantity. Durum is now incorporated in mixtures of other wheats for bread-making.

Club wheat (*T. compactum*) is white wheat grown mainly in the Pacific States of the United States, often on irrigated land, and in parts of Asia. Mixed with other wheat its cultivation is widespread. It grows well as a spring crop on poorer soil than ordinary wheat requires. Its grain is white, soft, and mealy and not well adapted for bread-making. It is classed in Class V, White wheats, in the American grading system.

Rivet wheat (*T. turgidum*) is not a suitable wheat for bread-making since its flour lacks strength, but otherwise it has a series of good points in its favour. It yields very well. It has 'a greater productive power than any other race of wheat' where the climate is mild enough to permit of it being sown as a winter crop, for it is not very hardy. It is immune to rust, has tall, stout straw, and stiff awns which protect it from damage by sparrows. It is grown on small areas in the south of England, and in small areas abroad. Its grain is characterized by a hump on the dorsal side immediately above the embryo. Its flour finds a ready sale for the manufacture of biscuits.

Dinkel or Spelt (*T. Spelta*) is grown over a large area in South Germany. It is winter hardy and very resistant to fungal

disease. The rachis of the plant is brittle and the grain remains invested by the chaff on thrashing, so that the product consists of the spikelet containing the ripened grain with a small piece of the rachis attached to it. To obtain the grain it is milled to loosen the chaff, sometimes after drying as in the husking of oats (p. 133). The grain is usually flinty, reddish, long, and pointed at both ends. The flour derived from it is excellent for confectionery and pastry, but not for bread when baked alone.

Emmer (*T. dicoccum*) is a very ancient form of cultivated wheat in which as in the previous species the rachis breaks up on maturity and the grain does not fall out of the chaff on thrashing. It is grown as a spring crop in South Germany in place of barley in the same area in which Spelt is raised. The grain is narrow and pointed at both ends, somewhat triangular in cross-section, is starchy and yields a specially white flour highly esteemed for the manufacture of the finest pastry and cakes.

Einkorn (*T. monococcum*) is a primitive form of wheat in which the rachis breaks up easily when the plant is ripe. The grain does not fall out of the chaff on thrashing. The grain taken from the chaff which invests it is 'yellowish and flinty, oval, and tapered at both ends, the outline of both dorsal and ventral surfaces being curved when the grain is viewed from the side. The radicle of the embryo projects prominently.' Einkorn is utilized in its husked state instead of barley for cattle and horses in the few districts of mid and southern Europe where it is grown.

Polish wheat (*T. polonicum*) is grown in small areas in the Mediterranean countries and also in the United States. It is a 'delicate spring cereal', with the largest grain of all wheats, in shape closely resembling rye. Its chaff is extremely leafy. Grains of it occasionally occur in imported North African barleys.

Of the two wild wheats, Wild Small Spelt is found as a wild grass on the hills of Thessaly, Bulgaria, and Serbia. The rachis is brittle and the grain tightly held in by the chaff. The grain is rice-like, flinty, and pointed at both ends.

Wild Emmer was discovered in 1906 growing in mountainous country in Palestine. The grain is very long, pointed at both ends, and triangular in cross-section.

VII

THE QUALITY OF WHEAT

THE imported wheats used by millers in Europe are derived from the countries whose wheat production has been considered briefly in the previous chapters. Including wheat grown in the importing country these may be classed as follows:

(*a*) Home-grown wheat.
(*b*) Canadian wheat, viz. Hard Manitoba, Northern Manitoba.
(*c*) American wheat, viz. Northern Spring, Hard Red Winter, Soft Red Winter, Durum, and White wheats.
(*d*) Argentine or Plate wheats, viz. Rosafe, Barusso, Baril, and Entre Riós wheats.
(*e*) Australian wheats.
(*f*) Indian wheats, viz. Choice White Karachi and Soft Red Karachi.
(*g*) Black Sea wheat.

Small quantities come in good years from Germany, Rumania, the Persian Gulf, Chile, and Egypt.

Each of these classes of wheat has its own characteristics. It has been observed that the term 'quality' applied to wheat has different connotations according as it is the farmer, the merchant, or the miller who is appraising it.

To the farmer a wheat of good quality is one which yields a heavy crop. Any other merit it might possess is of secondary importance to the supreme one of yield. The soil and climate of his district will set limits to the class of wheat he can grow. Within the class he will select that variety which experience has shown to be the best yielder for his particular farm and for his agricultural practice. Its success will be judged by its yield, which is expressed in bushels per acre. This figure multiplied by the acreage gives the production in bushels. Sale of wheat is now universally by weight,[1] so that the production by weight

[1] This is so in all the L. C. T. A.'s contracts, and, by the Corn Sales Act, 1921, also for sales within this country.

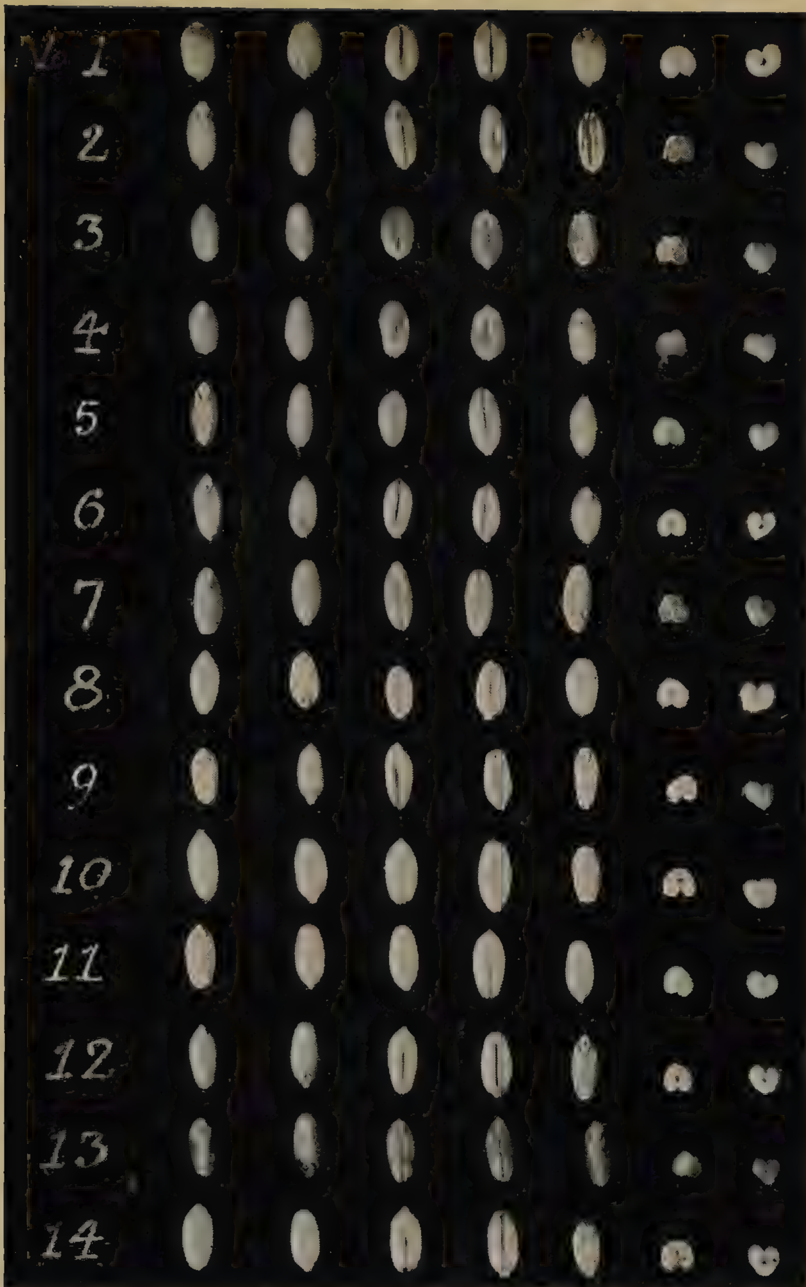

FIG. 4. WHEATS MILLED IN THE UNITED KINGDOM

(Natural size)

1. English, Standard Red
2. English, Yeoman
3. Hard Manitoba
4. No. 1 Manitoba
5. American Hard Red Winter
6. American Soft Red Winter
7. Durum (American)
8. Pacific White (American)
9. Plate
10. Australian
11. Choice White Karachi
12. Soft Red Karachi
13. South Russian (Ukraine) Spring
14. Chilian

is also a matter of great concern to him. The ratio of the latter to the former is the 'weight per bushel', or the 'natural weight', which for wheat varies between 55 lb. and 66 lb. It has long been known that the yield of flour from any given class of wheat increases with the increase in natural weight, and in consequence 'natural weight' is a figure of great significance and must be taken into account in any standards set up to regulate commercial transactions.

At the other end of the chain is the judgment of the public on what constitutes a good loaf. Leaving aside the question of the merits of their choice for another chapter, we may say that the demand is for a large loaf, rather moist, even, silky-textured, elastic, and of a very light cream colour with a thin good golden brown crust.

The baker works to meet this demand, and he requires from the miller flour which enables him not only to make bread with these characteristics, but also to make the largest possible number of loaves from a sack of 280 lb. of flour. His estimate of the flour will be decided by the number of such 4-lb. loaves he can bake from the sack, and this in turn depends on the capacity of the flour to absorb water and still retain its consistency in the dough.

To supply such flour the miller seeks wheats each of which contributes its characteristic qualities. Loaves of equal weight made from flour milled exclusively from each of the available kinds of wheat differ much in size. A flour (or a wheat) which can be made to yield 'a well aerated loaf of large volume' is known as a strong flour, and the wheat a strong wheat. The miller then will judge the quality of wheat according to the strength of the flour it yields and its capacity to absorb water. But he also will be mainly concerned with output. It has been noted above that yield of flour, while varying from class to class, is proportional to the weight per bushel within the class. He will therefore want wheat with a high 'natural weight'. Other factors which determine the quality from the miller's point of view are the 'condition' and 'cleanness' of the wheat.

The term 'condition' has its own connotation from the commercial standpoint, and is distinct from quality. A wheat in good condition is dry, bright, of good colour, cool, and sweet to smell and taste. A wheat which is out of condition may be damp, dull, dark, caked, warm or even hot, and will possess an unpleasant

smell and taste. Dampness either originally in the grain or absorbed at some stage after harvest is the determining cause of such unsoundness. As long as the moisture content has not exceeded 13·5 per cent. since the grain went into store it will remain in good condition. In a wider sense the presence of broken and country-damaged grain may perhaps also be included under this heading.

By 'cleanness' is meant freedom from weed seeds, chaff, straw, dirt, garlic, and smut, and from other cereal grains and other kinds of wheat than that constituting the bulk.

Requirements of commercial standards. For the purpose of international trade in grain, standards of quality must be adopted upon which to base contracts for sale. Thus, each contract of the London Corn Trade Association contains a warranty as to quality. The merchant buys from the producer and sells to the miller. His standards must therefore reflect the main points of quality as these two regard them. At first sight this may seem an impossible task, but it is immensely simplified by the fact that the customary classification given at the beginning of this chapter already groups together those characteristics which may be thought of as inherent in the kind of wheat. These are strength, colour, flavour, and water-absorbing capacity, or what may be grouped together as baking qualities. Thus the reputation of each of the above classes is well established in these respects, although it varies with the season, so that the merchant is only concerned with these qualities to the extent that the wheat sold is actually that named, for instance, Barusso and not Entre Rios, and free from admixture of another class.

Of the factors common to all wheats those chiefly to be considered in setting up standards of quality are seen to be natural weight, freedom from dirt and foreign seeds, and freedom from admixture of grains of other kinds of wheat. On the count of condition, the standard may be expected to give a guide to the permissible moisture content of the grain, the presence of broken grain, of country damaged grain, and of grain damaged during storage or transport.

Examination of the various methods of fixing standards upon which sales may be effected reveals an interesting evolution in complexity of these methods. At its simplest the standard is the selling sample which the buyer examines and agrees to.

Here his personal judgment is paramount. He integrates rapidly in his mind the various factors upon which quality depends and decides (or makes an offer) according to his skill and experience. At the other end of the scale is the 'grade' in which the value of each characteristic is separately ascertained by measurement and is independent of the judgment of the buyer. Between the two comes the method of ascertaining quality by which fair average standards are set up: arbitration involving personal judgment in comparison with the standard is then the custom.

VIII

MERCHANTABLE QUALITIES

THE points of quality mentioned in the previous pages fall naturally into two groups. The first group includes the factors which depend on the nature of the wheat. These we may term *inherent or baking qualities*, and they include colour, flavour, strength, and power to absorb water. The second group includes those factors which depend on the vagaries of the season, and the care and attention bestowed on the crop by the cultivator from seed-time to harvest. These we may call the *merchantable qualities*, and they include the natural weight, the purity and cleanliness of the grain, and its condition. The condition will be largely determined by the water content both at the moment when its condition is being judged and also at any previous period, if at any time the grain has become damaged by excessive moisture. The merchant is hardly concerned with the inherent quality of the wheat. Beyond its description it is not mentioned in the contract. Yet he must take into account the fact that the hard wheats such as Manitobas and Hard Winters may replace each other relatively in the mill, and similarly, medium wheats such as Karachis, Australians, and Plates, and again, soft wheats such as English, Red Winters, and soft Pacific wheats.

Merchantable qualities. The commercial designation of the wheat indicates to the buyer the *kind* of flour which will be produced, and this is known by its bakehouse reputation. The merchantable qualities decide the *quantity* of sound flour which will be obtainable from a given weight of a consignment of a particular class of wheat. Chief among the factors with which the merchant is concerned is the weight per bushel. Long experience, confirmed by much recent experimental work, has put the weight per bushel as the most important single factor by which the merchantable quality of wheat may be judged. It is true that the weight per bushel alone will not indicate the

weight of flour which can be milled from a given weight of wheat, for different classes of wheat permit of different percentage extractions. Hard Red Spring wheat, for instance, may yield 69 per cent. of straight run flour, Hard Red Winter 73 per cent., Soft Red Winter 72 per cent., Durum 71 per cent. But within the same class the weight per bushel governs the yield of flour fairly closely. Moreover, other factors which are known to reduce the yield of flour, such as the presence of foreign seeds, broken grain, high moisture content, &c., also reduce the weight per bushel. Consequently the weight per bushel is a reliable index of merchantable quality. The correlation (*a*) between the weight per bushel and the yield of flour, and (*b*) between the weight per bushel and other factors influencing it will next be considered in more detail.

Natural weight and yield of flour. (*a*) *Of a given variety.* The weights of flour which may be milled from a given weight of several grades of a given variety of wheat differing in weight per bushel increase with the increase in the weight per bushel of the cleaned wheat.

The United States Department of Agriculture gives the following table correlating weight per bushel with weight of 'straight' flour, summarizing the results of experimental milling on three years and including all varieties:

Weight in lb. per Winchester bushel (cleaned and scoured wheat).	*Pounds of straight flour from 60 lb. of wheat.*	*Equivalent to percentage extraction.*
64	44·1	73·5
63	43·7	72·8
62	43·6	72·7
61	43·0	71·7
60	42·5	70·8
59	42·2	70·3
58	41·7	69·5
57	41·5	69·2
56	41·0	68·3
55	39·7	66·2
54	39·4	65·7
53	38·8	64·7
52	38·4	64·0
51	38·3	63·8

Again, the average working extraction on cleaned and conditioned Manitoba wheats varies with the grade: No. 1, 73 to 75 per cent; No. 2, 72 to 75 per cent.; No. 3, 70 to 74 per cent.; No. 4, 69 to 73 per cent.

(*b*) *Of different varieties.* While the above correlation exists between the weight per bushel and the yield of flour for any given variety, the yield from two different varieties of the same natural weight is generally different, since the proportion of bran to endosperm and the ease and precision with which they may be separated in the process of milling differs from class to class.

Thus the average yield of straight flour from each of the five classes of American wheats is given in the United States Department of Agriculture, Bulletin 1183,[1] as follows:

	Percentage straight flour.
Hard Red Winter	72·0
Soft Red Winter	71·1
White Wheat	70·7
Durum Wheat	70·6
Hard Red Spring	69·3

The following average percentage working extractions on cleaned and conditioned wheats also illustrate the variation due to variety, but these figures of English practice are not comparable with those just given:

	Percentage.
Australians	74–6
Soft Pacifics	73–6
Choice White Karachi	70–4
Red Winter	73–5
Northern Spring	72–5
Hard Winter	72–4
Plates	68–72
Russian	68–72
English	68–70½
German	68–70½
Durum	66–69

This difference in the average percentage yield of flour from the commercial classes of wheat is to some extent correlated with differences in the average natural weight of each class.

Averaged over long periods to minimize the incidence of seasonal variations, the average natural weights of the various commercial wheats are by no means equal.[2]

[1] *Milling and Baking Experiments with American Wheat Varieties.*

[2] The effect of seasonal variations on the quality of the crop is then apparent by the difference from year to year in the percentage of the crop which comes up to the requirements for the higher grades. Thus in 1920,

The following table for instance shows the average weight per bushel of certain classes of American wheats:

		lb. per Winchester bushel.
Hard Red Spring	1919	59·2
	1920	55·6
	1921	56·5
Durum	1919	61·1
	1920	58·4
	1921	58·7
Soft Red Winter	1919	59·5
	1920	57·3
	1921	58·8
Common White Wheat	1919	58·3
	1920	58·3
	1921	57·7

The American grading system recognizes this average difference in weight per bushel by fixing the weight requirements for the grades for Hard Red Spring wheat lower than for the remaining classes. Thus the requirement for Grade I, Hard Red Spring, is 58 lb. per Winchester bushel, and for other classes 60 lb. per Winchester bushel. A similar recognition of the anticipated differences in natural weights is found in the standards of various wheats tenderable under the Liverpool Futures Contract (see p. 68).

Influence of moisture content of grain on the natural weight. The amount of moisture contained in normal dry wheat as it arrives in the United Kingdom ranges from 9 to 15 per cent., rarely overstepping these limits. The mean figure is fairly characteristic of each commercial class of wheat imported. Typical figures are tabulated on p. 62, where the 'condition' of wheat is considered.

When grain is exposed to the external air its moisture content varies with the humidity of the air, although the variation is usually small. There exists an equilibrium between the moisture content of the grain and the percentage humidity of the air, so that dry grain ventilated by moist air gradually increases its

29·1 per cent. of the class Hard Red Spring satisfied the requirements for Grade I, whereas in 1921, 43·1 per cent. reached Grade I. For Hard Winter, again, only 7·6 per cent. satisfied the requirements for Grade I, in 1920, whereas in 1921, 23·0 per cent. graded Grade I.

total weight as it absorbs moisture, its moisture content thereby rising to a new equilibrium. On the other hand, moist grain exposed to dry air loses weight and becomes drier. Thus, four samples of Australian wheat successively exposed experimentally for several days to air of 40 per cent., 60 per cent., 70 per cent., and 80 per cent. humidity by suspending the samples in a muslin bag in a strongly ventilated humidity chamber at 60° F. appeared to reach equilibrium at 8·25 per cent. moisture, 10·25 per cent., 10·35 per cent., and 11·69 per cent. respectively. This represents an increase in weight of 3·44 per cent. over the range of humidity at 60° F.

To set against this increase in *total* weight, when wheat becomes moister each grain swells so that its volume increases; in consequence fewer grains are required to fill a given volume and the weight per bushel falls. If wheat be immersed in water for a quarter of an hour, then dried with a cloth, its weight per bushel will be found to have fallen 6 or 7 lb. per bushel. The fall in quality weight amounts to about 0·7 lb. per bushel for each percentage increase in moisture.

The weight per bushel of wheat is thus a good indirect index of the moisture content of the grain.[1] This is illustrated by the grades of Manitoba wheat, on typical samples as received.

	Natural Weight. (*lb. per bushel.*)	*Moisture Content.*
No. 1 Manitoba	66	11·00
No. 2 „	$64\frac{3}{4}$	12·00
No. 3 „	64	13·50
No. 5 „	$61\frac{3}{4}$	14·20

This is the reason why no direct mention of moisture content is made in the London Corn Trade Contracts. The weight per bushel is in the circumstances a sufficient guide to the dry weight of the grain.

The influence of foreign material on the natural weight. Common impurities again depress the weight per bushel of

[1] The falling off in weight per bushel when dry wheat is moistened is intensified when weevil is present. Thus after eight days four samples of the same slightly weeviled Australian wheat, which had been arranged to contain respectively 11, 14, 17, and 19 per cent. moisture, weighed 62·75, 59·0, 53·0, and 52·0 lb. per bushel. The samples were kept at 90° F.

wheat, with the exception only of sand, which increases it considerably. The average weight per bushel of the common weed seeds and of chaff are all less than that of wheat, and mixtures of wheat with each of these show in most cases a depression fairly proportionate to the quantity of weed seed present. The packing effect which might be expected to destroy the proportionality does not do so, or only to a negligible extent, except in the case of light, irregularly shaped material like chaff, bromegrass, or kinghead vetch.

The weights per bushel of the common seed impurities in wheat are: vetch 63 lb., rye 61 lb., linseed 52 lb., wild rose 52 lb., mustard 51 lb., barley 47 lb., darnel 44 lb., corn cockle 43 lb., chess 35 lb., oats 34 lb., wild oats 31 lb., kinghead 28 lb., bromegrass 13 lb., chaff 4 lb.

Since the proportionality of the depression is fairly direct for different percentage admixtures, it may be taken that a given natural weight of clean wheat will be lowered by the admixture of an impurity by an amount equal to the difference in the weight per bushel of the impurity multiplied by the percentage present. Thus a 2 per cent. admixture of corn cockle will lower the weight per bushel of 62 lb. clean wheat by $(62-43) \times 0{\cdot}02$ lb., or about 0·4 lb. per bushel.

Again, therefore, the natural weight appears to be a satisfactory index of the quality of wheat.

Natural weight and seasonal influences. That the weight per bushel of wheat varies from season to season in the same district is well known. For instance percentages by weight of the total shipments of grain which satisfy the requirements of the Canadian and American higher grades vary from year to year as indicated in the footnote on pages 48 and 49.

The precise influence of the rainfall on the weight per bushel does not appear to have been investigated, whereas the effect of rainfall on the yield per acre has been carefully studied. If it is assumed that the seasonal conditions which favour high yields also favour high quality as judged by the weight per bushel, then the main desideratum is rainfall during the growing period (April and May in England) followed by dry, sunny weather until harvest (June, July, August). For winter wheat a cold or wet winter is bad, and especially a heavy rainfall during the period of germination and early growth of the seedling

plants.[1] Each of these observations has good theoretical justification. Heavy winter rains wash out the soluble salts from the soil and prevent the proper aeration of the soil, and rain during the growing period is necessary for the formation of the plant body and for the formation and transport of its food.

Rust, smut, and frost all reduce the weight per bushel considerably. Rust takes its toll by diverting to its own ends the supplies of food manufactured in the leaves and stored in the leaves and stems and destined for the infilling of the ears, which in consequence remain thin and undeveloped. In 1916 for instance, a year when rust did great damage to the Canadian crop, only 11 per cent. reached the Grade I requirement of 60 lb. per bushel. Smut and bunt actually perform their life processes within the ear and convert the carbohydrate and protein of the ear into the light black spores of the fungus. Frost does most damage when the grain is still in the milk stage. In this condition the ear is shrivelled and the damage is irretrievable. If the frost comes after the carbohydrates are well transferred into the seed, the only visible effect is a slight powdering of the pericarp. But the yield of flour from such frosted grain is small, because the final transformation of sugars into starch in the ripening grain has been hindered by frost.

In warm countries, as in India, the Argentine, and Australia, weevils may do considerable damage. This again is reflected in the fall in weight per bushel, especially in stored grain.

In sum, therefore, it may be said that the untoward circumstances of the season all make for a lower weight per bushel in the wheat, so that again on this count reliance on weight per bushel as an index of merchantable quality is justified.

[1] Shaw gives the formula 39·5, less five fourths of the rainfall for the months October, November and December in inches, as summarizing the statistics of yield per acre in bushels of the Eastern Counties of England in the latter half of last century.

IX

THE MEASUREMENT OF NATURAL WEIGHT

SINCE natural weight is a figure of all round importance to the merchant in judging the quality of wheat, its precise estimation has been a matter of close attention.

Units. In England, Canada, and Australia the natural weight is expressed as the weight in lb. of an Imperial bushel, while in the United States the unit of volume is the Winchester bushel. Since the Imperial bushel has a volume of 2218·19 cubic in. and the Winchester bushel 2156·42 cubic in., it follows that the latter is 0·969 of the former. The Winchester bushel is consequently about 3 per cent. smaller than the Imperial. Sixty lb. per bushel (Imperial) is $60 \times 0{\cdot}969$ or 58·14 lb. per Winchester bushel. Sixty lb. per Winchester bushel is $60 \div 0{\cdot}969$ or 61·9 lb. per Imperial bushel.

On the metric system the customary figure is the weight in kilograms per hectolitre (100 litres). Since 1 hectolitre = 2·7512 bushels and 1 kilogram = 2·20462 lb., weights in kilos per hectolitre may be converted into lb. per Imperial bushel by multiplying by $\frac{2{\cdot}20462}{2{\cdot}7512}$ or 0·8012. Thus, 78 kilos per hectolitre $\doteq$ $78 \times 0{\cdot}8012 = 62{\cdot}49$ lb. per Imperial bushel. Conversely, weights in lb. per bushel are converted into kilos per hectolitre by multiplying by $\frac{2{\cdot}7512}{2{\cdot}20462}$ or 1·248. Thus 60 lb. per bushel is equivalent to $60 \times 1{\cdot}248$ or 74·88 kilos per hectolitre. These equivalents are tabulated on Form 73 of the London Corn Trade Association.

Difficulties in accurate determination. Simple as the operation of weighing a bushel of wheat may appear, it is in practice difficult of achievement unless a standard instrument is employed, uniformity of procedure adopted, and great care is exercised. The difficulty of fairly ascertaining the natural weight arises from five possible sources of error associated with each of the following items. A measure (*a*) of known volume is (*b*) to be

filled with grain (*c*) levelled off so that the measure is full. The filled measure is (*d*) to be weighed and (*e*) its weight to be multiplied by some factor to bring it to the weight per bushel. At each stage errors are likely to be introduced.

In the first case (*a*), the measure may not have the precise volume it is reputed to have. If the measure is small (say one half-pint), any small error is immensely increased by the fact that it is multiplied by the number of times its reputed volume goes into a bushel, in this case 128 times. It is essential therefore that small measures should be accurate. For the same reason it is preferable that the measure should be large, for in that case any slight error in the capacity is not multiplied greatly. The volume adopted by the London Corn Trade Association is 20 litres (approximately ½ bushel). The volume adopted in the United States for the purpose of grading is 1 Winchester quart.

(*b*) The operation of filling the measure with grain leads to a variety of results according to the method adopted. It is an elementary observation that the extent to which grain packs and settles when it is filled into a container depends on how the filling is carried out. Moreover, the slightest jar to the full measure makes the grain settle closer.

The consequent variation in the result is not avoided by filling the measure from a hopper unless some standard size of orifice and height of fall are agreed upon.

Among the grain investigations of the Bureau of Agricultural Economics at Washington were a series of experiments showing that the grain packs tighter (within limits) in the measure the narrower the stream and the farther the fall. Thus wheat streaming into a quart measure from a hopper placed at 2 in., 3 in., and 4 in. respectively above the measure through orifices of 1 in., 1¼ in., and 1½ in. diameter respectively gave the following weights per bushel:

Wheat.

Diameter of hopper opening in inches.	*Weight per bushel in pounds when the distance of the hopper opening above the kettle was*		
	2 in.	*3 in.*	*4 in.*
1 in.	61·20	61·32	61·45
1¼ in.	61·14	61·25	61·34
1½ in.	61·08	61·16	61·20

As a result of these investigations the size of orifice agreed upon for the preferred form of American instrument was $1\frac{1}{4}$ in., and the vertical distance from the top of the 'test kettle' 2 in. This instrument (the Boerner) is adopted for the purpose of grading United States grain, and is illustrated in Fig. 7.

Other instruments in use in international commerce also avoid this source of error by arranging that the hopper or cylinder from which the grain is delivered is placed in a fixed position with reference to the measure into which the grain is filled. The Sommer and Runge instrument (p. 58) has an unusual device for securing that the grain shall fall similarly into the measure each time it is filled. This is described under the name of the instrument.

A much more subtle effect of the variation in the degree of packing of grain within the container is revealed when a comparison of the natural weight of a given sample is made on several *accurate* instruments of different capacities. The results expressed as weights per bushel or kilos per hectolitre will not accurately tally.

Thus there are four instruments which may receive the official guarantee of accuracy of the German Normal Eichungs-Kommission, namely instruments with capacities of $\frac{1}{4}$ litre, 1 litre, 20 litres, and 100 litres. Will the results expressed in kilos per hectolitre obtained by multiplication from each of the first three smaller measures actually equal the experimental result of weighing 100 litres? In other words, is it legitimate to use any instrument smaller than 100 litres (or smaller than one bushel) to ascertain the weight of 100 litres (or the weight of one bushel)?

Exhaustive experimental investigation of this problem has been carried out by the above authority and the results are recorded in the well-known tables for use with the above four instruments (among which are included the Louis Schopper 20-litre and the Sommer and Runge 1-litre instruments).[1] As stated above there is a well-recognized divergence between the results obtained by instruments of different capacities. However, the divergence is less than 0·5 kilo per hectolitre (i. e. 0·4 lb. per bushel) within the limits expressed in the following table, using the instruments named:

[1] *Tafel zur Vergleichung der Angaben der eichfähigen Getreideprober*, 3rd edition. Julius Springer, Berlin, 1909.

	¼ *litre.*	1 *litre.*	20 *litres.*
WHEAT. *Range.* 53–66 lb.	58–65 lb.	56·25–64·2 lb.	
RYE. *Range.* 52–64 lb.	53 lb. and upwards	52–61 lb.	Always
OATS. *Range.* 31–48 lb.	38·5 lb. and upwards	42·6 lb. and upwards	
BARLEY. *Range.* 40–60 lb.	44·8 lb. and upwards	45·6 lb. and upwards	

It follows therefore that when an accuracy of 0·4 lb. per bushel is sufficient, a *good* ¼ litre (half-pint) apparatus is satisfactory except for grain of inferior quality or in the case of wheat and rye of quite superior quality. For accurate correlation of the kilos per hectolitre or pounds per bushel with the weights obtained by using the smaller instruments the tables above referred to must be used.

The reasons for the difference between the calculated and observed figures above discussed are that grain packs differently (1) according to the quantity present and the consequent pressure to which it is subjected; and (2) according to the area of the walls of the container where it naturally lies differently from its position within the mass.

(*c*) Striking the excess grain from the brimming measure is an operation which is very apt to depend on personal idiosyncracy. It is performed in American grading by the instrument shown in Fig. 10, according to the following instructions: 'Strike the excess from the top of the overflowing kettle in a uniform manner with three full zigzag motions with the sides of the special stroker held vertically, avoiding any jarring of the contents.' The stroker should be of hard wood $\frac{3}{8}$ in. thick, $1\frac{3}{4}$ in. wide and 12 in. long, each edge being a perfect half circle (see also p. 122).

With care this method is of course satisfactory, but a mechanical removal of the excess grain is certainly preferable. This is effected in the Sommer and Runge 1-litre instrument (Fig. 6) and in the Schopper 20-litre instrument (Fig. 5), and thus the influence of the personal factor of the operator is excluded.

(*d*) The weighing is carried out by suspending the measure at the end of the arm of a balance. In the Louis Schopper and Sommer and Runge instruments the arms are equal and the weights placed on the left balance pan are equal to the weight of the grain in the measure. No error of the instrument arises here. But in the steelyard type of balance the arms are unequal and the long arm is graduated to read lb. per bushel directly, thus effecting the necessary multiplication mechanically. Except with a well-made machine the error due to inaccuracy of beam reading may be considerable, but at the same time it may counter the effect of error in the capacity of the measure, and, moreover, on good instruments the apparatus may be adjusted.

(*e*) Finally, there is the question of multiplying the weight of the fraction of a bushel actually weighed to bring it to the weight per bushel. This has been discussed in paragraphs (*b*) and (*d*).

The Louis Schopper 20-litre balance. This apparatus (Fig. 5) fulfils in the highest degree the requirements that should be demanded of an instrument of precision for ascertaining the natural weight of grain. It consists of a massive column carrying two equal balance arms from which are suspended on knife edges, by chains on the left and right respectively, the platform designed for the weights and the measure containing the grain to be weighed. The empty measure exactly balances the unloaded platform. In front of the central column a conical hopper of 24 litres capacity is rigidly built in. The orifice is closed by a hinged shutter which may be released mechanically.

In the absence of the measure, the grain would on release from the hopper, fall directly through an opening in the platform beneath it into a drawer. Upon the platform a pair of rails is placed so that the 20-litre measure which stands on a carriage provided with small wheels may be moved with ease from the position it occupies when it is suspended from the balance arm to a position directly beneath the orifice of the hopper. The hopper is filled with grain by means of a 24-litre container, *C*. The empty measure is run beneath it. The hinged shutter is released by a trigger mechanism operated by a handle *H* and the grain falls into the measure and fills it, the excess grain overflowing through the opening already described into the drawer below. A metal screen, part of which is fixed to the carriage on which the measure is mounted, prevents the surplus grain from

becoming scattered and directs it through the opening into the drawer beneath. The instrument is massive and rigid enough to ensure the absence of vibration which might cause the grain to settle. The surplus grain is separated from the measure by the release of a steel plate which is cut to a V-shape with knife edges and is released by the catch *A*. This plate moves horizontally on wheels along guides across the surface of the measure, being drawn by heavy weights as in a guillotine. The measure being now perfectly full, and the surface level, is moved back to its original position and refastened to the balance arm. By the operation of a lever *L* the balance is set free to swing, and weights are placed on the left until equilibrium is established. The instrument is sensitive to one gramme on 100 kilos. The weights are read, checked and counterchecked, and Table 3 of the German Imperial Standards Commission employed to determine the corresponding weight in kilos per hectolitre. Suppose for instance the weight required to balance the 20-litre measure of wheat is 15·140 kilos: this by computation ($\times 5$) would be equal to 75·70 kilos per hectolitre; but by reference to the tables, the true weight is 76·05 in accordance with the reasoning given on p. 56, and this is equivalent to 60·9 lb. per bushel. This instrument eliminates from the successive operations necessary in determining the weight per bushel practically every error which could result from the personal factor.

The main drawbacks to its general adoption are its massive construction, which makes it necessary to install it permanently in its place, and its cost (to-day about £330). It is eminently suited to the requirements of an international organization like the London Corn Trade Association which concentrates its work in one centre.

The Sommer and Runge balance. The balance of Sommer and Runge (Fig. 6) is made both in $\frac{1}{4}$-litre and 1-litre sizes and consequently serves as a portable apparatus. It consists of a small balance with equal arms, from one of which is suspended a cylindrical litre or $\frac{1}{4}$-litre measure *A*, and from the other a pan upon which weights are placed. The cylindrical measure is of special construction. Its base is perforated and the rim is separated from the cylinder and bolted to it by two small castings, leaving a slit *SS* into which the plate *P* with its V-shaped knife accurately fits. To use the instrument the cylindrical measure *A* is fixed in

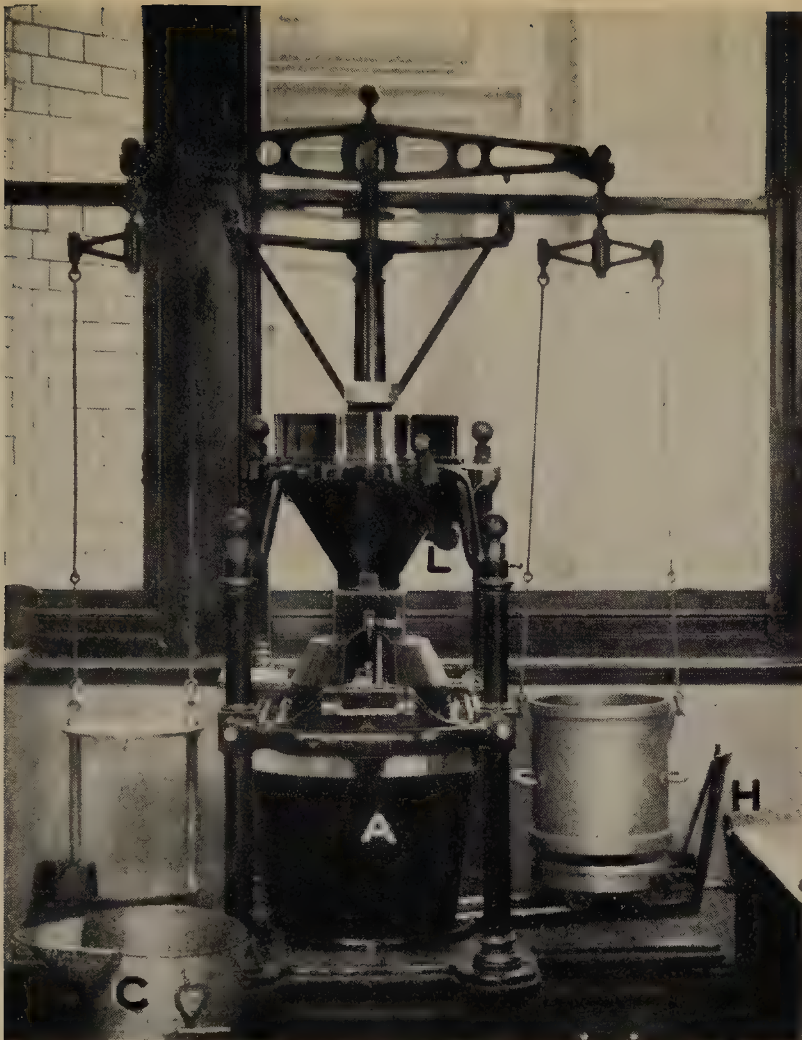

Fig. 5. THE SCHOPPER 20-LITRE GRAIN BALANCE

By permission of the London Corn Trade Association

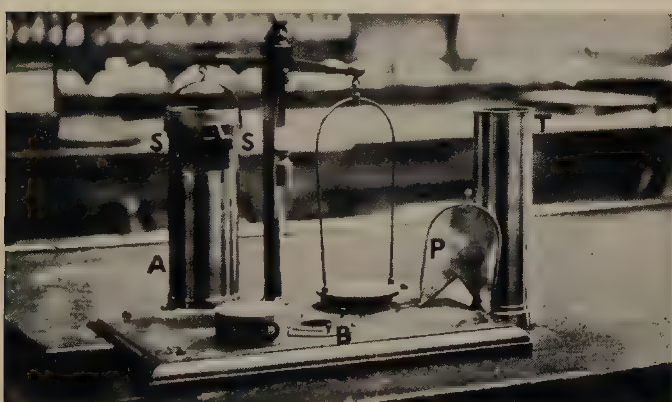

Fig. 6. THE SOMMER AND RUNGE 1-LITRE GRAIN BALANCE

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position in front of the balance by the three brass stops *B*. The knife *P* is then inserted up to the handle. Upon the surface of the knife the metal die *D* is next placed. This consists of a cylindrical ring closed at each end, and it fits accurately into the cylinder like a piston. Next the cylindrical tube *T* is firmly fixed upon the rim of the lower cylinder *A*. The grain is now poured into the upper cylinder until the latter is full. The knife is withdrawn, the piston falls with a heavy thud, driving the air out of the perforated base. The air pressure falls in the measuring cylinder and draws the grain after it. The impact occurs before the grain has filled the measure. On pressing home the knife again the surplus grain is divided from that which accurately fills the measure, and any grains caught between the walls of the measure and the knife are severed. The upper cylinder is now removed, the excess of grain thrown away and the measure containing the grain weighed. To compute the weight per hectolitre corresponding to the weight per litre it is only necessary to move the decimal point one place to the left. But for accurate inference of the weight per hectolitre tables must be employed.

Suppose, for instance, the litre of grain weighs 785 grammes. This should by computation correspond to 78·5 kilos per hectolitre, but by experiment (from the Tables) the corrected weight is 78·9 kilos corresponding to 63·2 lb. per bushel (Imperial).

The Boerner apparatus. This (Fig. 7) is the preferred form of apparatus for grain grading in the United States. It consists of a Winchester quart 'test kettle' filled from a hopper containing the grain to be tested, struck level, and suspended from the short arm of a steelyard. The long arm of the balance consists of two bars carrying poise weights, which are graduated as follows:

Lower Bar.

Top line:	1–60 lb. per bushel
Middle line:	½ oz. to 2 lb.
Bottom line:	1 to 100 per cent. of 2 lb.

Upper Bar.

Top line:	1/10 lb. to 13 lb. per bushel
Middle line:	2 grm. to 200 grm.
Bottom line:	1 per cent. to 100 per cent. of 200 grm.

From the above account of the graduations of this instrument it follows that it may be used (*a*) to find weights per Winchester

bushel, by moving the poise along the top line of each bar; or (*b*) to weigh an object in pounds and decimals of a pound, or in grammes and decimals, by using the middle and bottom lines of each bar, and (*c*) to find the percentage of damage in a sample weighing 200 grammes after handpicking.

On account of the fact that grain is graded at a very large number of points in the United States, much publicity has been given to the correct use and care of this instrument. It is by no means so well made as the Sommer and Runge instrument, nor as the small weight-per-bushel tester (not here shown) in common use in London.

The McGuirk machine. The weight per bushel of wheat submitted for grading under the Liverpool Corn Trade Association's Contracts for Future Delivery is ascertained on a machine in which a complete bushel is weighed. The grain is filled from a hopper having a circular opening of 8 in. diameter, 2½ in. above the bushel measure. Both the hopper and the measure are struck level with a fin, the round edge of which is used. The balance has equal arms, and weights are used to counterpoise the measure of wheat. The results obtained by the use of this machine have been stated to be ¾ lb. per bushel lower than those obtained on the Schopper 20-litre instrument.[1]

[1] *The Grain Trade of the Argentine*, E. V. Couche, Liverpool Corn Trade Lectures, December 1926.

Fig. 7. THE BOERNER WEIGHT PER WINCHESTER BUSHEL APPARATUS

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X

MOISTURE CONTENT AND CONDITION

WHEN a sample of sound dry grain is carefully examined, grain by grain, it is rare that some slight damage is not observed. In such an examination it is essential that the grain should be scrutinized in a good light, preferably in a north light. The use of a hand lens or a binocular magnifier is a great advantage. The f.a.q. grain standards described on p. 85, which are representative of a given class of grain shipped from a given centre during a given period will naturally contain a representative percentage of such defective grain. Arising as it does in the field such damage is referred to as 'Country' damage.

Country damage. Rain at harvest, frost during the ripening period, or the activity of pests produce a variety of changes in the grain. Some grains may be discoloured, dull or darkened, due perhaps to rain at harvest. Some may have germinated through the same cause. The rootlet will be shrivelled and the damaged germ can be recognized with a lens. Green unripe grains are not uncommon in some samples. When grain has been frosted after it is ripe the pericarp or outer skin of the grain has a lightly powdered appearance as if it would rub off. If the grain has become heated through excessive moisture during storage the kernels will be quite dark and in bad cases dark and soft.

Again, some grains may be damaged by fungi. Stinking smut gives the sample the unpleasant odour of bad fish, and the spores of smut may dust sound grain and darken it. Pink grains may be present, due to the fungus Gibberella. Mustiness is at once detected by the smell, but is perhaps hardly to be regarded as 'country' damage.

Finally, the grain may have been eaten by insects, although live insects are absent.

Moisture in wheat. The factors which control the condition of grain on storage are the following: the percentage moisture

in the grain, the kind of grain, the length of time in store, the average temperature, and the humidity of the air which has access to it.

The first-named factor, however, is the only predisposing cause of deterioration, the others simply governing the extent of the damage and the rate at which it progresses. In other words, dry grain does not go out of condition even when the storage temperature is high and the grain is stored for long periods.

Commercial wheats do not all contain the same percentage weights of moisture. The average moisture content of each class and grade, however, is fairly characteristic of each, especially through any one season, although it cannot be said to be *constant* for each class. Individual shipments may show appreciable divergence from the average.

Average figures for various classes of wheat dried for six hours at 110° C. are as follows:

Class of wheat.	*Percentage moisture.*	*Class of wheat.*	*Percentage moisture.*
English	15·6 (and over)	1. Red Winter	13·5
German	15·6	2. Red Winter	14·0
1. Manitoba	12·75	Pacific white	11·5
2. Manitoba	13·25	Plate	12·5
3. Manitoba	13·50	Indian	11·5 [1]
2. Hard Winter	13·0	Australian	11·75 [2]
Durum	13·5	Chilian	11·5

No direct reference to the moisture content of the wheat is made in London Corn Trade Association Contracts, although this figure is of considerable importance to millers, seeing that flour is sold with a constant moisture content of about 14·5 per cent. The reasons for this apparent omission are (1) that millers know the average moisture content of the wheat they are buying, and this knowledge influences the price they are willing to pay, and (2) the moisture content is taken account of *indirectly* in the contract.

The maximum limits of moisture content for each grade of wheat graded in Canada and the United States are fixed, so that when wheat is bought on grade named in the contract the

[1] This is the average moisture content of Indian wheat arriving in England during the last three seasons. Prior to this the average was between 10 and 11 per cent.

[2] The new crop Australian wheat arrives with 10·5 per cent. moisture, but the average for the whole crop is about 11·75, as it increases in moisture content as the crop is kept. (J. Gordon Hay, F.I.C.).

maximum allowable moisture content is prescribed. When wheat is sold with a guarantee of natural weight, named in the contract, this figure indirectly takes account of the moisture content, for it falls as the moisture content rises, as discussed on p. 50. As soon as the moisture content rises beyond the safe figure for export and the grain is damaged as a result, the contract provides for the issue by the terms governing the condition of the grain on arrival. These are given on p. 70.

Moisture content and grading. The fact that the keeping qualities of grain depend on its moisture content is recognized in the grading systems of Canada and America. Thus Canadian grain is graded 'No grade', 'tough', when the moisture content is above 14·5 and below 17, and 'damp' when above 17. The grain must then be dried prior to storage. The American requirements are specified more closely still in the United States Grain standards (p. 79). It has been observed that with regard to wheat, flinty grain can safely carry a slightly higher percentage of moisture without subsequent damage to the grain than soft wheat. Thus for Hard Red Spring the maximum moisture content in No. 1 wheat is fixed at 14 per cent., whereas for Winter wheats it is fixed at 13·5 per cent. The corresponding figures for maize, oats, and rye are 14 per cent., 14·5, and 13 per cent. respectively. These figures are based upon the statistical investigations of the Bureau of Agricultural Economics.

Investigations bearing on the relationship between moisture content and damage to wheat in store are carried out yearly by the same authority. During the period July 1917 to October 1919, 6,240 car-loads of Hard Red Spring wheat came under the notice of the Federal Grain Supervision Authorities as being out of condition. The moisture contents of these car-loads was determined and correlated with the percentage wheat which was heating, musty, and sour.

These figures show that practically all such wheat coming within the moisture requirements of Grade I, i. e. with a maximum of 14 per cent. moisture, was sound. Two and a half per cent. of the car-loads of wheat fulfilling the requirements of Grade II, i. e. with a maximum of 14·5 per cent. moisture, was sour, musty, or heating. This percentage increased to 3·2 for wheat with the requirements of Grade III, namely 15 per cent., and to 10 per cent. for wheat containing between 15 and 16 per cent., that is

fufilling the requirements of Grades IV and V; while of those car-loads with a moisture content above 16 per cent., 21 per cent. were heating.

Similar statistical evidence of the importance of moisture content in governing the condition of grain in storage is published for all other classes of United States wheat and for oats and maize.

Moisture and heating. Experimentally the effect of moisture content on the keeping properties of grain can be studied by using small samples stored in open thermos flasks. The sample may then be regarded as isolated from the centre of a large bulk, without disturbing too much the insulating effect that the bulk exercises on the small constituent sample. If some device such as this is not adopted, any heat generated by the grain in the small sample is rapidly dissipated, and there will be no correspondence between the behaviour of the grain in the sample and in the bulk.

By this device it is easy to show that dry grain does not develop heat, but that as the moisture content is increased, a point is reached, usually at about 13·5 to 14 per cent., above which every slight addition of moisture is accompanied by a marked increase in the heat developed.

As an instance, wheat was kept as follows:

Flask.	*Moisture Content.*	*Temperatures °C.*				
No.	*Per cent.*	*1st day.*	*2nd day.*	*4th day.*	*5th day.*	*6th day.*
1	11	30	31	34	33	33
2	14	27	30	33	33	34
3	17	29	32	39	41	42
4	19	32	34	45	46	46

Grain which has at any time become heated in this manner can be recognized by its dullness, its unpleasant smell (which may be mouldy), and by the presence of darkened or 'burnt' berries. The vitality of the grain is lowered and it may even fail entirely to germinate. It will have developed a sourness which is noticeable by smell, and is measurable with caustic soda.

The influence of the temperature of the store on the keeping properties of grain depends on the moisture content of the grain. If the grain is dry the temperature has little effect, but it is otherwise with grain in which the moisture content is above the

safe minimum. This is the common experience of shippers of maize, a grain which is likely to contain more than a safe minimum of moisture.

Nine cargoes consisting of upwards of fifty parcels of maize were shipped to Europe from the United States under experimental conditions.[1] An examination of the record of the condition of these parcels on discharge and their position with regard to the ship's heat, whether adjacent to the engine-room, boiler-room, or tunnel, shows that (*a*) the comparatively dry grain arrived sound, although in one instance it was stowed next to the boilers, (*b*) that moist grain, even when quite free from ship's heat, is liable to become damaged, and (*c*) that moist grain adjacent to ship's heat invariably became damaged.

Prior to the establishment of regular shipments of bulk wheat from the North Pacific Coast to Europe through the Panama Canal, the Dominion of Canada Grain Research Laboratory made observations on an experimental shipment which showed that the grain could be satisfactorily carried. They recommended that 'until some limit is definitely set, a moisture content of 14·5 per cent. should be regarded as dangerous'.

Method of determining moisture content. With regard to figures expressing the moisture content of wheat it must be borne in mind that the method of ascertaining the moisture content has great influence on the result. This is carefully considered by D. W. Kent-Jones in *Modern Cereal Chemistry*. There are four methods in common use, and while each method yields results which are strictly comparable among themselves, the different methods yield different figures. The methods are as follows: (1) By the Brown and Duval Moisture tester described on p. 81. (This is adopted in American Grading.) (2) By means of a water-jacketed oven. The temperature inside the oven is generally at 98·5° C. or below, and the grain is dried for 24 hours. The figures obtained by this method are consequently low. (3) By means of an electric oven. The length of time of drying is here reduced to 4 hours since the temperature is maintained at 101° to 104° C. A still higher temperature is sometimes employed, and the length of time correspondingly reduced to 20 minutes. (4) The drying is carried out by means

[1] *Factors influencing the Carrying Qualities of Corn.* Bulletin 764, U.S. Dept. of Agriculture.

of a vacuum oven. In Methods 3 and 4 the figures obtained are much higher than by the common Method (2).

Marine out-turn. Wheat almost invariably weighs less when delivered ex ship in Europe than it weighs when placed on the ship in the exporting country. The only fairly consistent exception to this rule is Indian wheat shipped between May 1 and July 15, and early arrivals of Australian wheat. The shrinkage on North American shipments is generally less than a half per cent. With Australian wheat the percentage loss is higher, ranging from ½ to 1 per cent.

The factors controlling the loss in weight are many and varied, but it depends partly on the methods of handling and the equipment for weighing at the ports of loading and discharge, and in this respect Italian, Spanish, and Greek ports are the least reliable. In consequence the average percentage difference in weight varies between port and port and from country to country.

Natural causes are also operative. The grain may have taken up moisture during the voyage or may have dried out. Further, there will be an inevitable natural loss in weight due to the carbondioxide given off by the wheat in respiration. This is entirely negligible as long as the wheat is in good condition (see p. 144).

London Corn Trade Association Contracts vary as to whether the loss in weight during the voyage shall be paid for by the shipper or not. Most of the contracts provide that the receiver shall only pay for net weight delivered. The most notable exception to this rule is in the case of North American wheat shipped in parcels to Liverpool and Manchester where the shipper guarantees that the out-turn will be within 1 per cent. of the Bill of Lading weight. Any shrinkage less than 1 per cent. is for the account of the importer.

On account of the above facts the importer invariably either:

(1) Pays for the weight of wheat actually delivered from the ship;

or on reselling to the Continent:

(2) Makes a calculation based on previous experience that the loss of weight will be a certain percentage;

or (3) Insures with an outside company the delivery of full weight ex ship, paying a premium to insure himself against shortage.

XI

QUALITY CLAUSES OF THE LONDON CORN TRADE ASSOCIATION'S CONTRACTS

EACH of the contracts of the London Corn Trade Association contains one or more clauses denoting the standard of quality against which the purchase is made. When these clauses present alternatives, as is frequently the case, one is to be struck out. The clauses differ slightly from contract to contract, even when their sense is much the same. Taken from the sixty-four contracts they fall into four groups, reading as follows:

(1) Sealed Sample.

'at time and place of shipment about as per sealed sample marked . . . in possession of . . .'

This is qualified in the Baltic oats contracts (No. 43) by the phrase

'due allowance being made for smallness, handling, and time out of bulk'.

Similar qualifications occur in United Kingdom offal contract (No. 63).[1]

(2) Fair Average Quality.

(*Standards made in London.*)

'Of fair average quality of the season's shipments at time and place of shipment.'

To this phrase is added in all Plate contracts (except No. 38)

'of the undermentioned weight',

[1] Qualifications of the f.a.q. warranty occurs in contract No. 63 relating to offal imported from the United Kingdom, viz. 'of f.a.q. and subject to the usual milling variation'; and in contracts Nos. 35, 36, and 37, specifying the maximum admixture of black oats which may be present in the f.a.q. standard.

after which follows the weight per bushel or per hectolitre referred to.

(3) Fair Average Quality.

(*Standards made in the exporting country.*)

'to average at time of shipment about equal to the official standard of the Chamber of Commerce of the State whence shipment is made' (Australia). Contracts Nos. 11–14.

This is varied in Contract 17 (Californian barley) to read:

'$\frac{\text{about equal}}{\text{superior}}$ to the Official Type Sample No. 1 of the Grain Trade Association of San Francisco Chamber of Commerce, of the crop 192– adopted by the London Corn Trade Association'.

Contracts 20 and 22 (Oregon and Washington wheat) refer similarly to the Official Type Sample of fair average quality of the Portland (Oregon) Chamber of Commerce, or of the Merchants' Exchange of Seattle adopted by the London Corn Trade Association.

(4) Certificate Final as to Quality.

'Official . . . certificate of inspection to be final as to quality.'

Certain contracts specify a warranty as to the natural weight of the particular shipment as follows:

Guarantee of Natural Weight.

'Natural weight of . . . lb. per bushel guaranteed at time and place of (loading or discharge) to be ascertained and determined according to the rules of the London Corn Trade Association for the description of grain sold.'

Future delivery contracts. The standards for the respective wheats tenderable under the Future Contract of the Liverpool Corn Trade Association are as follows:

'American Red Wheat:

Spring Wheat. If of the type known as Manitoba, basis of weight 60 lb. If of the type known as Northern (grown in the United States), basis of weight 60 lb.

Any other type of Spring wheat, basis of weight 60 lb.
Soft Winter Wheat, free from garlic, basis of weight, 61 lb.
Hard Winter Wheat, basis of weight, $60\frac{1}{2}$ lb.

ARGENTINE WHEAT:

Rosario. Santa Fe type, basis of weight, 59½ lb.
Bahia Blanca type, basis of weight, 60½ lb.

AUSTRALIAN WHEAT:

Victorian
South Australian } basis of weight, 60½ lb.
New South Wales

No wheat shall be graded, which, in the opinion of the Grading Committee, has any defect which would render it unsuitable for general milling purposes.

Subject always to this proviso, basis wheat may contain some heated, sprouted, frosted, and/or smutted grains, and a proportionately increased quantity may be allowed if warranted by an improvement in weight or in other respects.

No wheat weighing more than one pound per Imperial bushel under the basis weight shall be graded.

No wheat which complies with the weight requirements shall be rejected on account of the presence of heated, sprouted, frosted, and/or smutted grains or other defects if, in the opinion of the Grading Committee, it is not more than one penny per cental inferior to basis quality.

The allowances, if any, shall be in gradations of not less than one halfpenny per cental.

The basis of weight as herein beforeprovided is per Imperial bushel at time of grading.

Spring wheats must be reasonably hard of their respective types, and all descriptions of wheat must be reasonably clean of their respective types.

American Red wheat must be wheat grown east of the Rocky Mountains in the United States of North America and/or Canada, except where otherwise provided.'

The samples submitted to the Grading Committee of the Liverpool Corn Trade Association are drawn from grain in warehouse at Birkenhead. The weight per bushel is determined on the McGuirk machine.

Admixture of foreign material. Certain contracts contain a so-called 'Admixture Clause' which lays down the terms upon which foreign seeds and dirt will be accepted with the wheat. In consequence each consignment is to be sampled, mechanically analysed, and hand-picked to determine the percentage admixture of impurity named in the clause. The necessity for clauses such as these has arisen in trading with countries which ship grain in an impure state, and the details of the clause vary with the extent and nature of the impurities commonly met with. Thus there are admixture clauses with provision for sampling and

analysis in East Indian contracts (Nos. 1 and 2), the Persian Gulf contracts for feeding stuffs (No. 19), Egyptian wheat contracts (Nos. 44 and 45), the Black Sea and Danube contracts (Nos. 48–52), Baltic oats and North Russian wheat contracts (Nos. 55–8).

Clauses relating to the condition of grain. Every contract contains some provision for the event of grain arriving in a damaged condition. The contract may be upon 'rye terms':

'*Condition guaranteed on arrival* (subject to any country-damaged grain, in the fair average quality of the season's crop): slight dry warmth not injuring the grain not to be objected to, but damage by sea-water or otherwise to be taken by buyer with an allowance for deterioration (except for country-damaged as above), calculated on a percentage based on contract price to be fixed by arbitration in London.'

Or it may be on *tale quale* terms:

'Shipment in good condition but *tale quale as regards condition on arrival.*'

In the first case the extent of the damage, if any, is ascertained according to the rules laid down in the contract, and its amount is deducted from the invoice; in the latter the buyer accepts the grain in the condition in which it arrives.

If grain shipped under a *tale quale* contract arrives in a damaged condition the buyer has no recourse against the shipper unless he has indisputable evidence that the grain was not shipped in good condition.

In certain contracts (45, 48, 50, 61, 62) the *tale quale* stipulation is carried to its full extent by the express statement 'damage by sea-water to be taken as sound'.

In 54, 55, and 57, the contracts are *tale quale,* but 'damage by sea-water' is 'to be taken with an allowance of 10 per cent. on the sea-damaged portion' and this comes nearer to the position under the 'rye terms' contract. Sale of graded grain, on certificate, is *tale quale* as to its condition on arrival, and the contracts are headed to that effect.

Particulars with regard to damage by sea-water receive still further notice in certain contracts. In contracts 1 and 9 the seller agrees that the buyer should reject 'sweepings and damage by sea-water or by condensation', and in 44, 56, and 58, such 'damage, if any, is agreed to be for seller's account'. In contracts 2 and 4

(not headed 'rye terms'), as in contracts that are known as on 'rye terms', damage by sea-water is to be taken by the buyers at an allowance to be fixed by arbitration in London.

Terms of Sale of Wheat from the Chief Exporting Countries.

North America. Canadian and American wheat is sold almost exclusively on terms according to which the buyer agrees to accept the grade on the certificate as final as to quality. This excludes the possibility of subsequent arbitration on this count, as also on condition on arrival, since the sale is *tale quale.*

Provision is made in the contract as also in the United States Grain Act, 1919, and the Dominion of Canada Grain Act, 1912, for sale by sample instead of by grade, but this procedure is rare in shipments abroad.

Grain from the Pacific Coast of the United States (and also from Chile) is sold either on sealed sample or on f.a.q. standards set up by the Grain Associations of the respective centres and adopted by the London Corn Trade Association. As far as wheat from the Pacific Coast of the United States is concerned, an endeavour is being made by the American grading authorities to enforce sale on certificate final terms (or on sample) as from all other parts of the United States.

Argentina. Wheat from the Argentine is sold f.a.q., with a guaranteed natural weight. As regards condition on arrival, sales are made both on *tale quale* and on 'rye terms', generally according to whether sold to the United Kingdom or the Continent. Form 66 of the London Corn Trade Association sets out a scale of allowances to the buyer in respect of departure from the weight per bushel guaranteed in the contract. Arbitration upon quality and condition takes place in London. These are the most favourable conditions to the buyers upon which grain may be sold.

Australia. Australian wheat is sold f.a.q. on standards set up by each Australian State and adopted by the London Corn Trade Association. Arbitration on quality takes place in London. On the count of condition the sale is *tale quale.*

India. Indian wheat is sold f.a.q., the standards being made

in London. The contract lays down the terms upon which foreign material is accepted, viz.:

> 'Any percentage of barley, pulse, and/or other feeding stuffs up to 2 per cent. to be taken and paid for as wheat; any quantity in excess of 2 per cent. to be allowed for by seller at one half the price fixed for settlement. . . . Any percentage of dirt, non-farinaceous seeds and other extraneous matter up to $2\frac{1}{4}$ per cent. to be allowed for by seller at the price fixed for settlement . . . and any quantity in excess of $2\frac{1}{4}$ per cent. at double the price fixed for settlement . . .'

Russia. Russian wheat is sold on sample. There is a guarantee of natural weight. The grain is generally sold on *tale quale* terms, although business is also done on 'rye terms'. There is a clause in the contract relating to the admixture of dirt.

XII

THE ESTABLISHMENT OF STANDARDS

Sale on sample or on type. The simplest method by which grain may be sold is on sample. A fair-sized sample of the grain for sale may be displayed on the Exchange, as in the Corn Exchange, Mark Lane, for inspection by prospective buyers.[1] The selling sample is taken from that displayed on the Exchange and is a fair sample of the grain actually to be delivered. The sample displayed, however, may be a 'type' sample, in which case it has not actually been drawn from the particular delivery contemplated, but is made up by the seller as representative of a particular class of grain for a particular period. Selling samples are usually made in duplicate, one open and one sealed. The open one is for use of the buyer in enabling him to decide whether arbitration is necessary.

When the sale takes place on the London Corn Trade Association's contracts, it is usual for the sample agreed upon by buyer and seller to be sealed by each and to be deposited in the safe keeping of the Association for production at the appropriate time for comparison with samples taken from the actual delivery, and perhaps for arbitration. The sealed sample is the mutually agreed standard in comparison with which any question regarding the quality or condition of the delivered grain is decided.

Fair average quality standards (f.a.q.). A very considerable quantity of grain is sold on these terms, particularly grain from the Argentine, from Russia and the Black Sea, from Australia, and from India. Many of the standards are made up and distributed by the London Corn Trade Association, while those which are not, but are made in the country of production, are adopted by the Association, the standard samples being available in the Association's headquarters above the Baltic Exchange.

As far as the f.a.q. standards made in London are concerned, the task of striking them is undertaken monthly by members of

[1] The contract in the above instance is the Note of Sale of the London Corn Exchange Co.

the Sectional Committees of the London Corn Trade Association, each committee being responsible for the standards of grain from the exporting country with which it is concerned.

Clear rules governing the sampling of cargoes to secure the samples required by the Association for the purpose of (1) ascertaining the natural weight of the grain, and (2) arbitration upon quality and condition are printed upon Forms 66 and 71 of the Association. All cargoes sold f.a.q. on London Corn Trade Association Contracts are so sampled at the port of discharge. It is from the samples which are drawn by the cargo superintendents acting for the parties to the contract for the purpose (1), above, that the f.a.q. standards are made up.

The two parties to the contract are required to dispatch to the Association a jointly sealed sample[1] taken during discharge of the vessel of two bushels of wheat for quantities of less than 1,000 tons and four bushels for larger quantities. The sacks used for this purpose are of a special quality and construction, making it impossible to tamper with their contents. They are the property of the Association. The sample is for the purpose of determining the natural weight of the grain comprising the cargo or parcel, and is also used in the establishment of the f.a.q. standard.

On arrival at St. Mary Axe the four-bushel sample, say 250 lb., of wheat is emptied upon the floor of the grain standards room, thoroughly mixed with wooden shovels, and weighed with great formality and accuracy on a 20-litre Schopper balance already described. Since 20 litres of wheat weigh approximately 33 lb. there is enough for repeated filling of the measure. Thus it is filled and its contents weighed at least five times, and the weight finally assigned to 20 litres of the sample is the average of the five readings.

For the purpose of setting up the standards small representative samples taken from each of the larger ones which have been so weighed are displayed in small open wooden bowls in order of their natural weights upon a table in the Association's rooms. For each cargo or parcel of each kind of grain sold f.a.q.

[1] Apart from this sample, Form 71 requires a further series of samples, namely, one sample of not less than 2 lb. for each 50 tons in the case of grain cargoes, or one sample of not less than 1 lb. for each 20 tons in the case of parcels for the purpose (2), above, of arbitration.

during a given month there is thus a corresponding representative sample. Its weight per bushel and the quantity it represents is written up. Members of the Grading Committee for the particular grain then review these samples, grouping them according to their natural weights in two or three groups, rejecting from each group any sample which does not fairly come within the quality and condition of the group. The standards are then made up by the officials of the Association, one for each group, by taking quantities of each from the bulk samples of grain to be included in the standard, proportional to the size of the shipments they represent. Each of the standards so made up is then weighed for natural weight and the figures published to the Trade. Thus on June 3, 1926, the Argentina Committee made the following f.a.q. standards for wheat shipped during the month of February 1926 :

Argentine Wheat.

	Kilos per hecto at time of discharge.	*February 1926, Shipments.*	*Lb. per Imp. bushel at time of discharge.*
1	72·7	Plate Wheat of the Province of Sante Fe (up river)	58·285
2	74·175	Bahia Blanca Barletta and / or Russo Wheat	59·468
3	76·675	Bahia Blanca Barletta and / or Russo Wheat	60·671
4	72·55	Barletta and / or Russo Wheat from Buenos Aires	58·165
5	74·475	Barletta and / or Russo Wheat from Buenos Aires	59·708
6	75·65	Barletta and / or Russo Wheat from Buenos Aires	60·651

For the purpose of arbitration on quality or condition of any of the shipments made during the month to which the standards refer, the representative arbitration samples mentioned in the foot-note on p. 74 are produced for comparison by the arbitrators with the f.a.q. standard governing the quality and condition of grain of about the natural weight which the particular consignment bore.

Graded wheat. North American wheat is sold nearly exclusively on grade. Grain moving eastwards to the storage ports of Fort William and Port Arthur is held up in Winnipeg while each car is sampled. By the time it arrives at the storage

ports the grade of each numbered car-load which has been determined in Winnipeg is known, and the grain can be loaded into the appropriate elevator containing other grain of the same grade. Grain moving westwards towards Vancouver is similarly sampled and graded at Calgary and Edmonton. In the United States grading is carried out at a very great number of centres but mainly at Kansas City, Minneapolis, St. Louis, Omaha, Chicago, and Duluth. In each case the grain loses its identity after it enters the elevator, and in consequence any appeal against the grade assigned to a car-load must be made before the grain has been discharged from the car.

On the arrival of a grain train at Winnipeg, either by day or night, a gang of samplers, who are servants of the Dominion Government, samples each of the 45 cars.

The work of sampling and resealing the cars occupies an hour. To secure the sample a probe of 65 in. in length and 2 in. diameter is thrust into the grain. It consists of two telescoped tubes each of this length, the inner tube being provided with a wooden handle. Both tubes are perforated with a series of eleven slots, each about 3½ in. long by 1 in. wide. The inner tube is divided into eleven separate compartments by transverse partitions. On turning the handle the slots may be made to coincide, or may be closed by the operator. The closed instrument is thrust into the grain with considerable force. The compartments are opened by twisting the handle. The grain enters and the compartments are again closed. On withdrawing the probe the contents are emptied on to a canvas.

Since each compartment is separate and its contents drawn from a known level in the car the uniform nature of the grain in the car can be confirmed. The operation is repeated several times and an average sample procured. About 3 lb. of this sample are put into a bag and taken away for grading as described on p. 80. The carload varies in weight from 60,000 to 100,000 lb. Special attention is paid to cars in which the quality of the grain is not found to be uniform.

The grading system. The establishment of grades for grain and provision for their uniform application to shipments in inter-State and foreign commerce is governed by the Canada Grain Act, 1912, and the United States Grain Standards Act, 1916.

In accordance with the former a Board of Grain Commissioners

consisting of a chief Commissioner and two others was appointed to administer the Act. Two classes of wheat are recognized, namely, Spring wheat and Winter wheat. Within each class the grade is defined (*a*) by weight per bushel; (*b*) by the percentage of admixture of other wheat; and (*c*) by a description.

This Act recognizes the following subdivisions of each class:

Spring wheat: Manitoba Hard, Northern Manitoba, Hard White Fife.[1]

Winter wheat: Alberta Red Winter, Alberta White Winter, and Alberta Mixed Winter.

Statutory grades. For spring wheat grown in the western division four statutory grades are defined, viz.: No. 1 Manitoba Hard; No. 1 Manitoba Northern; No. 2 Manitoba Northern; No. 3 Manitoba Northern. Definitions describe the wheat of each grade and set a minimum weight per Imperial bushel and a minimum percentage of hard Red Fife or Marquis for the first three grades. The requirements may be summarized as follows:

No.			*Minimum weight in lb. per Imperial bushel.*	*Percentage requirements Hard Red Fife or Marquis.*	*Description.*
1	Manitoba	Hard	60	75	Sound, well cleaned
1	,,	Northern	60	60	Sound, well cleaned
2	,,	,,	58	45	Sound, reasonably clean, of good milling quality
3	,,	,,	Discretion	Discretion	Discretion

These grade requirements do not vary with the season. Since the quality and condition of the crop taken as a whole is, however, a direct outcome of each varying season, a large and varying percentage of the crop does not meet these requirements. In consequence the Grain Standards Board sets up annually a number of *commercial* grades suitable for the grading of that part of the crop which falls outside the requirements of the fixed statutory grades in that particular year. These commercial grades are known as No. 4, No. 5, No. 6, or by other designations

[1] Very little grown. 'Goose' or Durum Wheat is also recognized as a class.

such as No. 4 special, according to the condition of the crop for the particular year.

Condition. Any of the above grades whether statutory or commercial may be qualified by the terms 'no grade', 'condemned', or 'rejected', and these terms refer to the condition of the grain at the time of grading.

'*No grade*' is the term applied to all good grain unfit for warehousing through being tough,[1] damp,[1] or wet, or from any other cause.

'*Condemned*' is applied to grain 'in a heating condition or badly bin-burnt'.

'*Rejected*' grain is unsound, musty, dirty, smutty, or sprouted, or contains a large admixture of foreign seeds, or is unfit to be classed under any of the recognized grades from some other cause.

The grades of the United States. The official grain standards of the United States Government for various grains were set up under the authority of the United States Grain Standards Act, 1916, and became effective at subsequent dates, and the requirements for each grade and for each cereal were decided upon after statistical inquiry and detailed experiment.

Five classes of wheat are recognized, each class containing two or three subsections. These are as follows:

Class I. Hard Red Spring wheat; subclasses (*a*) Dark Northern Spring, (*b*) Northern Spring, (*c*) Red Spring.

Class II. Durum wheat; subclasses (*a*) Amber Durum, (*b*) Durum, (*c*) Red Durum.

Class III. Hard Red Winter wheat; subclasses (*a*) Dark Hard Winter, (*b*) Hard Winter, (*c*) Yellow Hard Winter.

Class IV. Soft Red Winter wheat; subclasses (*a*) Red Winter, (*b*) Western Red.

Class V. White wheat; subclasses (*a*) Hard White, (*b*) Soft White, (*c*) Western White.

The requirements of the various grades are more precisely defined in the American grading system than in the corresponding one in Canada. The American system aims at 'providing for the establishment of a single set of standards of quality and condition for the various grains'. Consequently the lower grades of American wheat corresponding to the commercial grades of

[1] Tough wheat has above 14 per cent. and below 17 per cent. water; damp wheat has above 17 per cent. moisture.

Canadian wheat are defined as precisely as the higher grades. Moreover, the subsidiary factors of quality and condition are also defined numerically with the object of introducing a consistent analytical procedure into the grading operations.

The grade requirements are as follows:

				Maximum limits of								
Grade No.	*Minimum weight in lb. per Winchester bushel.*			*Moisture.*		*Damaged kernels.*		*Foreign material other than dockage.*		*Wheats of other classes*		
	Cl. I.	Cls. II, III, IVa, V.	Cl. IVb	Cls. III, IV, V. Percentage.	Cls. I & II.	Total per cent.	Heat.	Total.	Matter other than cereal grain.	Total per cent.	*a.*	*b*
1	58	60	58	13·5	14·0	2	0·1	1	0·5	5	2	2
2	57	58	56	14·0	14·0	4	0·4	2	1·0	10	5	3
3	55	56	54	14·5	15·0	7	0·5	3	2·0	10	10	10
4	53	54	52	15·5	16·0	10	1·0	5	3·0	10	10	10
5	50	51	49	15·5	16·0	15	3·0	7	5·0	10	10	10
Sample												

(*a*) White and/or Durum in Class I or II; Soft Red Winter and/or White in Class II.

(*b*) Durum in Classes IV or V.

N.B. 58 lb. per Winchester bushel = 59·8 lb. per Imperial bushel.

'Sample grade' is the term applied to 'wheat of any particular class which either does not come within the requirements of any of the Grades Nos. 1–5, or which has any commercially objectionable foreign odour except of smut, garlic or wild onions, or is infested with live weevils or other insects injurious to stored grain, or is otherwise of distinctly low quality, or contains small inseparable stones or cinders.'

Besides the above schedule, certain requirements in further description of the condition of the grain are contained in the definition of the standards.

In contrast to the Canadian practice, the operations of sampling and grading are not carried out by officials of the Federal Government but by inspectors who after a proficiency examination in the routine of grain grading, have been licensed to perform such work by the Department of Agriculture at Washington. These inspectors are not in the employ of the State, but derive their incomes either from fees charged for grading, or more commonly they are employed by a local authority or a Chamber of Commerce.

The representative sample of the grain from the car-load of grain is obtained in a similar manner to that described in a previous section dealing with Canada.

The grading of grain in Canada.[1] When the sample arrives at the Winnipeg Grain Inspection Laboratory it is graded. The essential principle of grading is the determination by means of instruments of the numerical value of certain factors which govern quality. These numbers provide a framework of ascertained facts to guide the personal judgment of the grader.

Dockage. In the first place the percentage of easily separated foreign material such as sand, dirt, weed seeds, stems, and chaff is determined. One pound of the sample is weighed out and put into a handsieve of standard pattern to separate small seeds. If buckwheat is present, a suitable screen with triangular perforations is employed to remove it. Large material is scalped off on a sieve that allows wheat to pass through. The foreign material both large and small thus easily separated is known as *dockage.* It is collected and weighed. Its presence does not affect the grade, but is taken account of as follows: The total weight of dockage in the consignment is calculated from the observed percentage and this is subtracted from the gross weight of the wheat sold by the farmer, so that the amount payable to the farmer is based on the weight of dockage-free wheat he delivers. The dockage is removed at the terminal elevators and sold as feed, so that exported wheat is dockage-free.

The determinations upon which the grade is based are made on the sample thus partially cleaned.

First, the weight per bushel is ascertained. An Imperial quart measure is filled from a hopper, struck level, and weighed on a steelyard arm.

Next the sample is examined for moisture. This is effected by touch. The grain is spread out on a sheet of brown paper. An experienced man is able to class grain as 'dry', 'tough', or 'damp' by fingering it. The moisture contents of doubtful samples of wheat, however, are determined experimentally by the Brown and Duval apparatus, about ninety tests per day being made in the Winnipeg Grain Inspection Laboratory.

The remaining tests are made by personal expert judgment. These are tests of condition, including the presence of shrivelled

[1] See A. H. R. Buller, *Essays on Wheat.*

or broken grain, frosted, smutty, pink, heated, or sprouted grain. The six standard grades are kept in boxes before the grader for purposes of comparison.

After grading, the samples are filed in a sample room where they are generally inspected by representatives of their owners. If the owner is dissatisfied with the grade assigned to the sample he may have the car-load re-sampled and graded when it arrives at Fort Arthur.

If the result of the re-inspection is not satisfactory to him he may appeal against it to the Winnipeg Survey Board, appointed by the Board of Grain Commissioners.

Grain grading in the United States. The procedure prescribed for grain grading in the United States is similar to that in Canada.

Dockage. One kilo of the grain is cleaned by the use of hand-sieves of specified design or by the use of a small mechanically operated machine known as a 'wild-oat kicker'. Ordinarily the dockage may be satisfactorily separated by the use of a fine seed sieve (diameter 13 in.; depth 2 in.) with round perforations $\frac{1}{12}$ in. in diameter together with a scalper sieve (diameter $12\frac{7}{8}$ in.; depth $1\frac{1}{2}$ in.) with round perforations $\frac{12}{64}$ in. in diameter.

The weight per bushel is next ascertained on dockage-free wheat. This is determined either on the Boerner Weight per Bushel apparatus, or on any instrument giving strictly comparable results to those obtained by the preferred apparatus. The volume weighed is one Winchester quart.

Moisture content. The Brown and Duval apparatus is customarily used for ascertaining this figure, but the use of other methods is permitted, provided the results obtained conform to those obtained by the Brown and Duval apparatus.

The principle of this apparatus is that the moisture in wheat may be distilled over by placing the wheat in a distilling flask, covering it with oil of high boiling-point, and heating it. When the temperature rises above 100° C. the water in the wheat is driven over and may be collected.

One hundred grains of wheat are placed in a round-bottomed flask having a bent delivery tube which conducts the water vapour through a condenser surrounded by cold water. 150 grains of mineral oil are poured on the wheat, and the flask closed with a rubber cork through which passes a centigrade

thermometer. The flame of a bunsen burner (or other source of heat) is adjusted so that a temperature of 180° C. is reached in 20 minutes. By this time all the water in the wheat will have been driven off and condensed. It is collected in a glass measuring cylinder graduated in cubic centimetres, so that the reading expresses the percentage moisture in the grain directly.

It is important that an apparatus of standard specification should be employed in this determination.

For the purpose of the determination of the remaining factors for which the United States Standards prescribe definite requirements, namely, the percentage of (*a*) damaged kernels, (*b*) foreign material other than dockage, (*c*) wheat of other classes, a smaller quantity of the dockage-free sample is hand-picked. This smaller sample is obtained from the larger by means of a reducing machine without the use of which it would be difficult to obtain a small sample as representative as the original. In assigning the grade to a given car-load from the above figures the principle adhered to is that the grade shall not be higher than its worst features permit.

The terminal elevator. A typical elevator consists of a working house containing, say, 120 bins, each with a capacity of 4,000 bushels, for dealing with incoming wheat, that is, for weighing it, cleaning or drying it if necessary, and for storing it temporarily. Then there is a number, say, 30 or 40, of silos or tanks for storage, each holding 40,000 bushels. The spaces between the cylindrical silos, the so-called star bins, are also used for storage and hold about 10,000 bushels each.

The silos are filled from wheat carried on an endless belt, which travels across the top of the group of silos and is made to discharge its stream through an open grating in the top of the silo. Thus the silo is never air-tight. To ship grain away, it is run from the bottom of the silo, re-elevated, weighed, and passed into shipping bins. From these it flows on to an endless belt along the wharf to the vessel's hold.

A silo can be emptied into the hold of a vessel in a couple of hours. As the grain leaves the elevator it is constantly watched by a grain inspector who takes samples repeatedly and checks the weight per bushel at a small table. He is empowered to hold up the discharge of grain whenever he notices a departure from the grade requirements.

Advantages of the grading system. The advantages of the grading system are many. It is essentially a farmer's system. It is his safeguard. Grading takes place in the country of production and it provides the required incentive to the farmer to farm well, since he has the assurance that his return will be determined by the quality of his crop. His grading certificate provides him with bank credit immediately. Then grading is the absolute pre-requisite of bulk handling. If grain is not graded, it cannot be bulked with other grain, but must retain its identity and be sampled frequently for selling purposes. The immense economy of the terminal storage system is only possible after dependable grading. Next, it provides the basis upon which organized marketing with future sales and hedging alone becomes possible. This forms the most economic machinery for financing the crop, paying cash to the farmer months before the grain is exported, holding it, transporting it, and getting it to the miller. Finally, it provides the last buyer with a standard article upon which he may depend, in the same manner that buyers depend on the trade mark of manufactured goods of reputable firms. The main disadvantage from the point of view of a European buyer is the impossibility of disputing the grade and securing arbitration upon questions of quality or condition when once the grain is sold on grade for shipment abroad. It thus appears to be essentially a system of an exporting country. It only becomes a possible international system on certificate final terms when experience shows (as it does) that the grading in the exporting country is entirely dependable.

Advantages of the f.a.q. system. The advantages of the f.a.q. system are its fairness to buyer and seller and its extraordinary elasticity. It is essentially the system of an importing country, for it provides the centralized machinery for regulating the quality of the varying imports month by month from a great variety of countries at different stages of economic development and producing varied qualities of grain. Grain is not invariable in its quality and condition month by month, especially from less well organized states, and this system provides the fairest method of settling questions arising out of the departure of each consignment from the standard in respect of quality and condition.

XIII

INHERENT QUALITY OF WHEAT

WE have seen that the qualities which are the chief concern of the merchant are those depending on the season and the degree of care exercised by the farmer in his methods of husbandry, namely, the weight per bushel, cleanness, and condition. On the other hand the inherent qualities of the grain which determine the kind of flour it yields are fairly independent of the season, nor are they affected by methods of husbandry.

The factors comprised in the term 'inherent quality' are many, and the chief may be enumerated as follows: (1) the colour of the flour derived from the grain; (2) its flavour; (3) the extent to which it will absorb water without losing its stability; (4) its 'strength'.

Each factor is important to the extent that it influences and determines the character of the loaf for which there is public demand. It cannot be too clearly stated that it is ultimately the consumer who pronounces upon quality.

'Strong' and 'weak' wheats. Leaving aside certain modern wheats to be considered presently, English wheats yield a flour which bakes into close-textured bread, so that the size of a two-pound loaf is small. Most wheats that are tough skinned, large-berried, and have soft floury endosperms produce similar loaves. Such wheats are known as 'weak' and the flour is said to be 'soft'.

Certain foreign wheats, notably Manitoba, Northern Spring wheat, and some Hungarian and Russian wheats, yield flour which bakes into a well risen, large, and shapely loaf, although of the same weight as that considered above. These wheats and their flour are known as 'strong'. They are typically smaller grained varieties, red, thin-skinned, and flinty. Their flour is characteristically granular.

The introduction of these foreign 'strong' varieties into England produced a change in the loaf which met with marked public

approval. To-day millers invariably mill a mixture of wheats, a considerable proportion of which is bound to be of the strong varieties.

The above-mentioned external features of the typically 'soft' wheat, the English wheats, like Benefactor or Standard Red, and the typically strong wheat, like Marquis, afford nothing more than presumptive evidence of strength or weakness in a sample of an unknown wheat. But one characteristic is more dependable in determining whether a given sample is strong or weak, and that is its behaviour when twenty or thirty grains are chewed. A strong wheat leaves an elastic pellet of gluten in the teeth, whereas no gluten can be separated by chewing a weak wheat.

However, the only certain method of deciding the strength (and the other baking qualities) of flour is by making it into bread. By this very practical method all the commercial classes of wheat have established reputations for strength, and although this varies from season to season and from sample to sample, it does so about a mean value.

The discovery that strong wheat would grow in England. Organized work has led to a working definition of strength and investigations into its nature date mainly from 1901, when Dr. A. E. Humphries chanced to grow Duluth wheat (Red Fife) as a late spring crop on his farm in Surrey. He observed that his crop, although small, was of the same inherent quality as that of the seed sown. Since this was unexpected, and contrary to the general belief that strong wheat grown in England invariably deteriorated even in the first harvest, he brought the facts to the attention of Sir Daniel Hall the Head of Wye Agricultural College.[1]

The outcome of the observation was the establishment of the Home-grown Wheat Committee of the National Association of British and Irish Millers. The investigations carried out under the auspices of this Committee, under Dr. Humphries's chairmanship, and similar investigation in other quarters have elucidated certain fundamental problems connected with the quality of wheat.

Working definition of strength. In the first place the investigation of the bakehouse behaviour of flour led to the working

[1] *English Wheat.* Lecture 7, City of London College, Grain Trade Lectures, 2nd Series, 1924.

definition of the term 'strength' as 'the capacity of the flour to yield a shapely well-aerated loaf of large volume'. In practice the strength of a given flour is measured by the difference in volume of a two-pound loaf and the dough from which it was made. The latter volume is taken as 850 c.c. The volume of the loaf is measured by placing it in a box of known capacity and filling the space left with millet or rape seed. The volume occupied by the seed is determined by running it into a measuring cylinder, and the volume of the loaf is then found by subtraction. This volume varies from about 2,500 c.c. for wheat from ordinary English varieties to 3,700 c.c. for Manitoba wheat.[1]

In order to obtain comparative results from different samples of flour it is necessary to adopt a standard procedure for making and baking the bread.

Since the procedure which would produce the best loaf from a strong wheat would not give the best results from soft flour, a set of standardized baking trials has been adopted, so that each flour is judged by the loaf made under conditions which suit it best.

One result of these investigations was the establishment of a scale of comparison of 'strengths' of bread from certain flours, based mainly on loaf-volume as outlined above. On this scale No. 1 Northern Manitoba and No. 1 Northern Spring are assigned 100 points; Russian Ghirka wheat 85; the average London loaf 80; Plate 80; Choice White Karachi 75; English wheat 65; Australian 70. These numbers simply provide a scale of comparison and are not intended to give a measure of the volume of the loaf.

Red Fife wheat in England. The observation that Red Fife wheat inherited from season to season its high milling and baking quality when grown in England stimulated investigation to ascertain whether other foreign strong varieties of wheat would also retain their strength on being grown here. The result of this research was to show that, with very few exceptions, noticeably that of Red Fife, almost all varieties of strong wheat rapidly ran down to the strength-level of ordinary English wheat. In some cases this deterioration took place in one season

[1] *See* The Home-Grown Wheat Committee of the Incorporated National Association of British and Irish Millers, Ltd., Chairman's *Report on the Quality of Yeoman Wheat*, 1920.

and in others by steps in successive seasons. Red Fife alone retained its quality undiminished over a long period of years, as successive reports on the baking quality of its flour amply demonstrate.[1]

This power of inheritance of strength from season to season exhibited by Red Fife is all the more unique since ordinary English varieties grown in countries where strong wheats predominate show no increase in strength. Moreover, endeavours to influence the strength of wheat by spring instead of autumn sowing, or by manurial treatment, fail.

Red Fife is not a wheat suited to our conditions, since it is a Spring variety and its yield per acre is relatively small. A wheat which will not produce an average crop of 32 bushels to the acre cannot be profitably grown in England. The varieties in actual cultivation, while capable of producing large crops, were all of inferior quality for bread making. The hope of producing a wheat which would combine the cropping capacity of such a wheat as Square Heads Master with the milling and baking qualities of Red Fife lay in the chance of breeding such a wheat.

The production of new varieties. There are two methods by which new varieties of cereals are produced. In the first place there is the method of ‘ selection ’.

(a) *By selection.* In an ordinary field of wheat, even when the seed is of one variety only, the individual plants show the slight variation among themselves characteristic of all living things. The idea of selecting a number of the best-grown plants of any variety and raising a fresh crop from the selected seed is very old. By repeating the process the endeavour is made to secure a better strain of the original variety. This method of selection has been the subject of critical investigation and is now discredited, mainly because the results of such selection have failed to improve upon the original from which they were selected. Variation in the condition of the plant is so much a matter of the accident of position in the field that the plants selected come to be those which happen to have been best fed, and this kind of variation is not inherited.

A second method of selection is also adopted, but one which eliminates the objections to the previous method. In this method

[1] *Report on the 21st year of English-grown Red Fife.*

(*a*) the excellence of a cereal plant is not judged by its own size and appearance, but by the size and appearance of its progeny; (*b*) care is taken that the result is not biassed by the accident that one plant is better fed or drained or lighted than another; (*c*) the selected seed is derived from one plant only. To carry out this selection grain from a series of individual plants is separately grown in adjacent plots and the produce separately harvested. The trial is repeated until there is enough grain from each of the original plants to sow in several small separate plots. When these are harvested it is possible by averaging the yield from all the plots sown with the produce of one original ear to eliminate very largely the effect of variations in the soil on the product of each ear and to compare the progeny of the various original individual plants for their yielding capacity (or any other quality).

The older methods by which comparisons of yields (and other qualities) of cereals have been made in the field have been shown to be unreliable in the extreme. Mainly through the work of Dr. E. S. Beaven, new methods capable of giving results accurate to within about 2 per cent. have now been introduced.

Pure lines. The second method of selection just described produces a stock of seed from one individual plant. Such seed, when raised from a fixed variety, is known as a pure line. A cereal crop grown from a pure line of a given variety has the great advantage over an ordinary crop of the same variety that the individual plants exhibit the greatest uniformity at all stages of growth, ripen together, and are of the same height. The same variety grown from ordinary seed exhibits fairly wide differences in individual plants as to time of ripening, height of plant, and other characters. The uniformity secured by starting with a pure line considerably raises the yield. Before proceeding with the method of breeding new varieties by cross-fertilization the logical method is to obtain the finest pure lines from all existing varieties and to use these in the breeding experiments.

(b) *By cross-fertilization.* The hope of raising new varieties of cereals is by cross-fertilization. Wheat, barley, and oats are self-fertilizing, so that the cross must be made before the anthers have shed their pollen on the adjacent stigmas: otherwise the breeder is forestalled by Nature. To effect the cross the chaff enclosing a flower on one parent plant is opened and the three

stamens with their unopened anthers removed with forceps. The pollen from the anthers of a flower of the second parent is then dusted on the receptive stigma. The chaff is then closed and the cross-fertilized ovary ripens to an entirely new grain bearing the potential characteristics of both parents.

Since cereals are normally self-fertilizing, the attempt has sometimes been made to improve the vigour of a given variety by crossing its flowers artificially among themselves. Seed produced in this way is known as 'regenerated'. Careful investigation of the effect of regeneration with Square Heads Master showed that no advantage is secured by such crossing and the crop remains unchanged.

Crossing varieties. It is otherwise when wheats of two different varieties are crossed. It has long been known that crossing two varieties of wheat produces an apparently heterogeneous collection of plants, some resembling one or other parent in certain respects, some exhibiting characters intermediate between the two parents. This fact has been used by breeders to establish new varieties by selecting from the resulting hybrids those that seemed desirable for further cultivation or crossing. Thus the famous Marquis wheat was bred by crossing Hard Red Calcutta wheat with Red Fife, which was the standard variety of wheat in Western Canada prior to Marquis. The object of the cross was to obtain, if possible, a wheat which combined the excellent milling properties of Red Fife with the early ripening feature of the Indian wheat, for Red Fife was apt to be caught by early frosts. Cross-fertilization had been begun as early as 1888 at Ottawa, and the cross from which Marquis was derived was made in 1892 by Dr. A. P. Saunders. It was not until 1904, however, that his brother Dr. C. E. Saunders selected it from the mixture of a very large number of types (including Marquis) which resulted from the cross.

The work of discriminating between the various hybrids which result from the crossing of two plants has been systematized by the discoveries of Mendel (1873). Mendel's laws of inheritance established by his work on garden peas remained unnoticed for three decades until De Vries brought the work to light in 1900. In the hands of Professor Sir R. H. Biffen the application of Mendel's laws to the breeding of new wheats has produced extremely important results.

Wheat breeding starts as before with the crossing of two varieties, but proceeds methodically to examine the resultant hybrids in the light of the knowledge of the way the plant characters are inherited. This knowledge enables the breeder to go straight to his objective, systematizing the scrutiny of the hybrids and greatly reducing the labour of selection.

Mendelian inheritance. Suppose, for instance, a bearded wheat be crossed with a beardless variety. The ripened hybrid grain is sown. When the hybrid plant is mature the ear is seen to be intermediate in respect of the length of awn between the two parents. If the grain from the hybrids is now sown, the second generation is made up of awnless varieties, awned varieties, and intermediate varieties. Counting the number of plants exhibiting each character, it is found that there are invariably two of the last named (intermediate) to one each of the former two (awned, awnless). Moreover, the awnless and the awned wheat each breeds true to this characteristic in successive seasons.

The hybrid with the intermediate character is not fixed in this way, and does not breed true, but yields in the next season awned, awnless, and intermediate varieties, again in the ratio of 1 : 1 : 2. The awned and awnless varieties again breed true, and the intermediate plants again split up in the next season in the ratio 1 : 1 : 2 as before.

If, instead of the presence or absence of awns, the laxity or density of ear differentiated the two parents, then the position would be similar. In the second generation of the cross there would be an equal number (1 : 1) of plants with lax ears and dense ears (like each parent) and these would breed true; and twice this (: 2) number which would not breed true. In this instance the hybrid plants which do not breed true are not, however, intermediate between their two parents in respect of the length of ear, but are lax-eared, so that the unfixed hybrids with lax ears cannot be distinguished from the fixed hybrids with lax ears in this generation. They must be bred on until the next season, when the fixed types can be isolated.

The reason for this difference is that certain plant characters dominate others, so that the crosses which contain the dominating character invariably reveal it. Among such dominants, as they are called, are awnless spikes, red chaffs, red kernels, hard kernels, and liability to rust.

What, now, is the position when wheats are crossed which differ in respect of a pair of characters?

Taking the previous examples of density of ear and presence or absence of beard as an example, suppose the cross is made between a bearded wheat with lax ears and a beardless wheat with dense ears. Then as far as presence or absence of beard is concerned, the second generation would show bearded plants breeding true, beardless plants breeding true, and intermediate plants which are unfixed. These will be in the proportion of 1 : 1 : 2, or out of 1,000 plants, 250 of the first kind, 250 of the second, and 500 of the third. Considering now the density or laxity of ear, there will be among the same 1,000 plants, 250 dense-eared plants breeding true, 250 lax-eared breeding true, and 500 lax-eared (indistinguishable at this stage from those just named) which will split up.

Combining these results it will be seen that among the 250 plants which possess beards and will breed true to this character, one quarter will have dense ears and will breed true to the character, one quarter will have lax ears and will breed true to this characteristic, and one half will have lax ears but will be unfixed with regard to this character. Thus a wheat possessing a combination of characters not originally present in the parents, namely, a bearded wheat with dense ears, has been bred and is fixed in type. Similarly a beardless wheat with lax ears has been produced.

The realization of the fact that each plant is thus composed of a number of characters, each of which can be dealt with independently of the others, opened a very wide field for experiment.

It was soon demonstrated by Sir R. H. Biffen, who was now co-operating with the Millers' Association, that characters of economic significance were also inherited in a manner similar to that of the inheritance of botanical characteristics such as presence or absence of awn. The quality of early ripening, of resistance to disease, of baking capacity and of cropping power were found to be hereditary units which could be separately considered. Thus arose the possibility of crossing a good yielding English wheat like Square Heads Master which is liable to rust attacks with a rust-resisting wheat like Ghirka, which is unsuitable to English conditions, and obtaining a good cropping wheat

which is not liable to rust—Little Joss. Similarly the work of combining in one wheat the excellent quality of Red Fife with the cropping power of English wheat (in this instance Grey Browick) was crowned with success in the production of Yeoman, which now shares with Square Heads Master the first place among the varieties grown in England.

The choice of parents from which to breed for new varieties better suited than those commonly grown in a given district is not limited to those wheats which are suited to the district. For it is possible to take as one parent a foreign wheat exhibiting some desirable character, such as rust resistance or the property of ripening early, but which from other points of view is quite useless for the district, and to cross it with one of the commoner varieties suitable to the district in order to introduce the desirable character into the commonly grown variety. The interest in the innumerable varieties of foreign cereals which otherwise would have remained academic has thus attained an unforeseen practical significance, and small plots of such wheats are grown in experimental stations for the purpose of cross-breeding.

Economic importance of the new varieties of home-grown wheat.[1] The successful introduction of Yeoman wheat into British agriculture opens up a prospect of far reaching change. Our dependence on foreign supplies for 87 per cent. of the wheat we consume has led to the concentration of the milling industry in the big ports, London, Birkenhead, Hull, Cardiff, &c. Thereby great economies in handling the imported grain have been secured and the necessity for its transport by land eliminated. The ports are also excellent strategic centres from which to distribute flour, for the dense industrial areas converge on them.

The country mills have suffered in consequence. The unsatisfactory bread-making quality of home-grown wheat has driven inland millers to bring in wheat from the coast to mix with it, and they have had to bear the cost of its transport. On the other hand, the excess of home-grown wheat which they could not use has to be sent to the port mills, where it comes into competition with the cheapest imported varieties. In consequence the return to the farmer has been inadequate and a lamentable decline in wheat growing has taken place in the country.

[1] *The improvement of Home-grown Wheat, its economic importance.* A. E. Humphries, LL.D.

With the introduction of home-grown strong wheats—Yeoman and Yeoman 2—this position can be partly retrieved. There is little reason why the mills in the country districts in the eastern and southern counties, where most of our wheat is grown, should not be practically independent of all other sources of supply than the local ones. The population of these counties is not large and they would become self-supporting in their bread supply. The cost of carriage would disappear and the wheat-growing industry recover. Moreover, the reduced supplies of soft wheats grown at home, which are excellent for biscuit manufacture, would raise their price. The advantage to the wheat farmer is thus twofold.

XIV

FLOUR

Gluten Content and Strength.

CONCURRENTLY with the researches mentioned in the previous chapter there has been close investigation into the causes of the strength of wheat. This work has been carried on not only from the desire to elucidate the underlying scientific principles governing strength, but also with a view to finding if possible a simple test to enable the chemist to make a reliable forecast of strength from the examination of a small sample of wheat or flour. Moreover, a complete understanding of the nature of the factors which combine to make a strong flour would guide the miller and the baker in their treatment of the flour to produce a uniform product.

Flour for bread making. Flour is made into dough by the addition of rather more than half its weight of warm water containing 1·25 per cent. of salt and from 0·5 to 0·75 per cent. of yeast calculated on the weight of flour. The dough is made uniform by kneading so that the yeast is distributed evenly throughout it. When the dough is left in a warm place it begins to rise. This is because each yeast cell produces the gas carbon dioxide by splitting up the small quantity of sugar which is present in flour. The gas produced is imprisoned within the dough and causes it to rise. During the long period of fermentation, which in practice may vary from four to eight hours, a large quantity of gas is produced, part of which escapes into the air. At intervals during the fermentation the dough is worked by hand so that it partly collapses by the loss of gas. It then begins to rise again. A short time prior to baking, the dough is finally kneaded and made into loaves. The gas which causes the loaf to rise when it is placed in the oven at 475° F. is consequently that produced at the end of the fermentation period. When the loaf is placed in the oven the imprisoned gas

expands. The size of the loaf then depends on how much gas escapes into the oven and to what extent each imprisoned bubble of gas can push up its retaining envelope of dough before the dough hardens and withstands the pressure of the expanding gas.

The conditions which produce a large loaf are therefore the following: (1) that enough gas is present in the dough at the time it enters the oven; (2) that the film of dough enveloping each bubble of gas is tenacious enough to retain this gas as it expands; (3) that it is distensible enough to be easily pushed up by the expanding gas before it hardens in the oven.

Gas production. The amount of sugar present in flour is less than 2 per cent., and this is the only substance which yeast can ferment. But this amount of sugar accounts for less than half the gas which is actually evolved during bread making. The remainder is derived from the starch of the flour by a subsidiary fermentation carried on by the enzymes of the flour and yeast, which convert starch into sugar and thus makes it available for the yeast. Consequently it is not the amount of sugar originally in the flour which sets a limit to the amount of the gas which may be produced, but the diastatic activity of the flour. This may not be very pronounced. To remove this possible hindrance to the proper development of the loaf it is customary for the baker to add malt extract or a small quantity of malt flour in making the dough.

To observe the production of the gas from a given sample of flour, 20 grammes are made into a dough with water containing yeast and salt, so that the dough contains 1 gramme of yeast and 0·25 gramme of salt. This is placed in a small bottle with a tightly fitting cork through which passes a gas delivery tube. The bottle is kept at a constant temperature of about 28° C. and the gas evolved is collected. The quantity given off per hour rises to a maximum in about the fourth hour and then falls off, sometimes to a very small quantity indeed. The free evolution of gas in the early stages of fermentation corresponds to the activity of the yeast in using up the sugar initially present. After this the production of gas depends on the supply of sugar which the activity of the diastase of the flour affords.

The active development of yeast depends not only on an adequate supply of sugar, but also on certain other foods, viz.

phosphates and nitrogen-containing substances, which may be insufficiently supplied by the flour; on this account yeast foods such as ammonium phosphate or acid calcium phosphate may be added at the rate of 4 oz. per sack of flour (280 lb.), or sometimes more.

The practice of milling flours from a mixture of various kinds of wheat makes it much more unlikely that the product would be deficient in respect of its power to produce sufficient gas for bread making than would be the case if wheats were separately milled. This defect, if present, may always be removed by a change in the mill feed or by longer conditioning of some of the wheats in the blend. The baker sometimes adds malt or yeast foods for the same purpose.

Retention of the gas. The next consideration is, then, the behaviour of the dough when it is distended by the gas. Experimentally this may be measured by allowing a supply of air under pressure to blow out a thin layer of dough until the bubble so formed bursts. The size of the bubble and the work required to burst it may be measured and used to determine the strength of the dough.

The reason why some flours are weak and others strong is not involved in this test. The cause of strength has been sought mainly by careful study of the behaviour of the gluten of the flour. It has been thought to depend (*a*) on the quantity of gluten present in the flour, (*b*) on the inherent quality of the gluten, (*c*) on the effect on the gluten of the soluble substances which are present in the dough. The effect of modern work is rather to discount the importance of (*a*) and (*b*) and to look for the explanation of strength in the effect of dissolved substances in the dough on the physical properties of the gluten. These three factors will be considered.

Gluten-content. When the gluten-content of various classes of wheat is estimated, the strong wheats are usually found to have the most gluten, and within the same class, e. g. Manitoba, the higher the gluten content the stronger the wheat, although even here exceptions arise. This correlation between high gluten-content and strength is comprehensible from the short account given above of the manner in which the gas is imprisoned in the dough; for it is the gluten which forms the continuous elastic film which gives the dough its character. An *a priori* view

would lead to the conclusion that if a wheat were rich in gluten it would make good bread.[1]

Typical gluten figures are: No. 1 Manitoba 13·5; No. 2 Manitoba 13·0; No. 3 Manitoba 12·0; Hard Winter 11·5; Durum 11·8; Plate 10·6; English 8·7; German 8·7; Pacific 9·0; Australian 11·0. Nevertheless, the amount of gluten in a flour is only in a very general way a guide to strength. Thus, Durum wheat is usually rich in gluten but it does not yield flour of good strength, and low-grade flours may have high gluten-contents and yield bad loaves.

The percentage of gluten in flour is usually expressed either as wet gluten, or as dry gluten.

(a) *Wet gluten.* The percentage of wet gluten in a flour is obtained by washing away the starch from dough containing a known weight of flour by kneading it in the fingers under running water. The residual piece of gluten is worked in the fingers so as to expose fresh moist surfaces, which are then lightly dried with a cloth. The gluten then holds what water it will naturally absorb. It is weighed, and its weight expressed as a percentage of the flour from which it was made.

(b) *Dry gluten.* To drive off the moisture, the wet gluten is placed in a water-jacketed drying oven, at 98·5° C. for 24 hours. It is then allowed to cool and is weighed. The dry gluten is expressed as a percentage of the flour from which it is derived. Ten grammes of wet gluten dry to a quantity between 3·1 and 3·4 grammes of dry gluten.

It will be seen from the above description that the reliability of the figure indicating the percentage of dry gluten depends on the assumption that the gluten is completely extracted by the process of washing. This is not so. The amount of gluten to be obtained by washing varies with the hardness of the water it is washed in, the length of time taken by the washing operation, the temperature of the washing water, and the technique adopted by the operator. Small quantities of salts dissolved in the water have a marked effect on the result. Consequently the gluten figures are only comparable when the same water is used for

[1] As far as food value is concerned, the more gluten the flour contains the more valuable the flour is, whether it is weak or strong (see Chapter XXII). The whole problem of its strength is secondary to the fundamental problem of food value.

all determinations and the operations and the conditions kept strictly uniform.

Partly for this reason and partly because the amount of gluten in a flour is not in any case a reliable index of its bread-making quality, the importance once attached to it has now declined. Thus, the American Association of Cereal Chemists have omitted the test from their published list.

Arpin has suggested the use of water of definite hardness (containing 100 mg. of lime per litre) to be used in the washing process. He proposes that 33·33 grammes of flour should be made into a dough in a basin with water run in from a burette. The dough is then washed immediately by kneading it in the fingers in a stream of the prepared water run from a large bottle. Small pieces of gluten which become detached are to be caught on a No. 6 silk placed in the sink below. The washing operation is to take 12 minutes. When the gluten is finally obtained it is dried in the manner described above, or put into an oven at 105° C. for 12 hours, and weighed as dry gluten. This figure multiplied by 3 gives the percentage gluten in the flour.

The usual method is the following or some slight variant upon it. An agreed amount of flour, say 20 grammes, is weighed out into a small basin. Tap-water from a burette is then run in while the wetted flour is worked up with a knife until a tough dough is produced. This usually requires just over half the weight of the flour taken. The ball of dough is then placed in a handbowl of tap-water and left standing for one hour, during which period it absorbs water. It is then kneaded by placing both hands in the bowl and working it beneath the water. The milky water (containing the washed out starch) is then carefully poured off, preferably through a silk gauze, and any small detached pieces of dough or gluten left in the basin or on the gauze are picked up. The basin is then refilled with tap-water and the operation repeated until the gluten is washed free from starch. The washing is completed in ten minutes. The gluten is then worked in the fingers to expose fresh moist surfaces repeatedly and so to remove adhering moisture. It is dried in a water oven at 98·5° C. for 24 hours or an electric oven at 104° C. for 12 hours. Alternatively, it is sometimes dried by being placed in a baking oven at 475° F., when it soon bakes into a large airy ball. It is then weighed.

From old or damaged flour the gluten cannot be washed out in a coherent mass at all.

Protein content. The method adopted in the case of wheaten flour to extract the gluten happens to be possible because of the peculiar physical properties of a typical gluten. The corresponding compounds in rye, maize, barley, and oats, namely, the proteins, of these cereals as of other food-stuffs cannot be washed out in this way. Moreover, the gluten of wheat is not accurately separated by the mechanical analysis described above, and it is not the only protein of the wheat—although it is the most important. The others are lost in the washing process. Consequently a chemical method of determining the total protein content of the cereal product is used. This method depends on the fact that the proteins of wheat contain 17·5 per cent. of nitrogen, and the quantity of nitrogen may be accurately determined by Kjeldahl's classical method. Thus if the flour is found to contain 1·50 per cent. of nitrogen, its protein content would be $1{\cdot}50 \times \frac{100}{17{\cdot}5} = 8{\cdot}57$ per cent.

The percentage of nitrogen in the proteins of maize, rye, oats, and barley are respectively 16 per cent., 17·8 per cent., 16 per cent., and 17·2 per cent. The estimation of the protein content of wheat is important because it is the most reliable single indication of the strength of a sample of any given variety.

XV

FLOUR

Acidity, Water-absorption, and Colour.

THE conclusion reached in the previous chapter was that the percentage of gluten in a flour is not a good guide to its strength.

Physical character of the gluten. The physical character of the gluten is a better index of strength than the quantity of gluten. Thus it has been remarked that strong wheats leave a tough pellet of gluten between the teeth when chewed. As ordinarily washed glutens from strong wheats are firm, tough, and very elastic; while those from weak flours are soft and easily stretch, or sometimes are firm, yet break short when pulled, like putty.

Again, wet glutens from strong wheats remain contracted and upstanding when placed on a flat surface, but those from soft flours flatten and spread.

But here it must be observed that the physical character of gluten is determined by the substances dissolved in the water it is washed in. These substances will be (1) the salts originally in the tap-water, and (2) the soluble mineral content of the flour itself: they profoundly affect the elasticity of the gluten. When gluten is thoroughly washed and left in distilled water it becomes soft but tough and elastic. On the other hand, in the presence of very slight quantities of soluble acid substances, it loses its coherence and makes the water milky. With an increase in acidity it becomes very hard and tough.

The acidity of flour. The strength of gluten is consequently dependent on the acidity of the liquid it contains, i.e. the acidity of the dough. The measurement of this acidity is not, however, the simple matter referred to on p. 110. The figure obtained by the usual analytical method indicates the total amount of acid present and is a guide to the age and soundness of the flour, but it is no guide to the strength of the flour.

Some confusion results in interpreting the analytical results on account of the varying manner in which the same estimation may be expressed. The determination is performed by titrating the liquid obtained by shaking 5 grammes of the flour in cold boiled distilled water with N/20 sodium hydroxide solution, using phenolphthalein as an indicator.[1] The result may be expressed as equivalent to a percentage of sulphuric acid, lactic acid, or potassium dihydrogen phosphate. The limits for sound flour expressed as sulphuric acid are 0·105 per cent. to 0·122 per cent.; expressed as lactic acid the figure is multiplied by 1·9, and as phosphate by 2·77.

Such figures as these do not, however, help in the problem of determining the requisite acidity of a dough for the development of the maximum strength of the flour. The reason for this is that the effect of acid substances on the physical properties of gluten is measured by the *intensity* of the acidity and not by its total amount. The figure representing the intensity of the acidity, or its so-called hydrogen concentration, can only be obtained by methods which it is beyond the scope of this book to discuss.

The chief naturally occurring constituent of the wheat grain which raises the intensity of the acidity of the dough and causes the exhibition of strength in the gluten is the soluble acid phosphate. Strong wheats contain more soluble phosphates than weak. It follows that an analysis showing the percentage of soluble phosphates in the grain would indicate its strength. Professor T. B. Wood[2] has described a simple test for strength depending on this fact. He observed that when flour is shaken in water to dissolve the phosphate and the mixture filtered, the filtrate comes through more or less turbid. Strong flours relatively rich in phosphates give a more turbid filtrate than weaker ones. This is because the acid phosphate dissolves some of the gluten. Consequently the turbidity measures the percentage of phosphate and this in turn indicates the strength of the sample.

[1] The method adopted by the Association of the Official Agricultural Chemists of the United States requires that the suspension should be filtered and the filtered solution titrated. The results are expressed as lactic acid.

[2] See T. B. Wood, *Story of a Loaf of Bread*, 1913.

An example of the test is as follows. Seven samples of flour were taken:

A	Straight Run	No. 2 Hard Winter.
B	" "	No. 1 Northern Spring.
C	" "	Choice White Karachi.
D	" "	Red Karachi.
E	Patent	Ordinary London Mixture.
F	Straight Run	Ordinary London Mixture.
G	Straight Run	No. 1 Manitoba slightly bleached.

One gramme of each was shaken with 20 c.cm. distilled water for one hour, then filtered. The turbid solutions were coloured with iodine to intensify the effect and the columns measured against each other for their opacity.

The lengths of the columns which matched each other in opacity were in the following ratio (inversely)[1]: G 102, E 100, B 99, A 75, F 68, C 61, D 60, and this is in the order of their strengths as judged by baking. The key to these flours was not revealed until after the tests.

Improvers. The conception that the strength of a flour is due to the action of soluble substances on the physical properties of the gluten has led to the addition of suitable chemical substances for the purpose of artifically strengthening the flour.

Among the commonest are acid calcium phosphate added at the rate of 4 oz. per sack to the flour, and ammonium persulphate added at the rate of ¼ oz. per sack, or more in proprietary articles containing this chemical. Both these substances have a marked effect on the behaviour of the treated flour in the bakehouse.

Water-absorbing capacity. The yield of bread from a sack of flour is more dependent on the amount of water that may be added to the flour in making up the dough than on any other factor. In consequence it is a figure of great importance. It is expressed in quarts per sack. A sack of flour weighs 280 lb. If it will absorb 60 quarts, i. e. 150 lb., the total weight of the dough is initially 430 lb., plus the weight of the yeast and salt added. During fermentation the weight falls on account of the escape of carbon dioxide and moisture. The loss during fer-

[1] The hydrogen ion concentrations of these samples were as follows: pH A 6·02; B 6·08; C 6·19; D 6·26; E 6·07; F 6·38.

mentation and baking may be put at about 10 per cent. With a flour which will absorb 60 quarts of water, the weight of bread produced will be about 387 lb., which is between 96 and 97 4-lb. loaves. The water-absorption figure usually lies between 60 and 64 quarts per sack.

Colour of flour. The colour of flour is the readiest indication of its quality. Freshly milled unbleached flour ranges in colour from white through all shades of cream to pale reddish orange. The colour is governed by the cleanness of the wheat from which it was milled and its freedom from impurities, by the natural colour of the milled endosperm of the wheat, and the extent to which the outer parts of the endosperm and inner coats of the pericarp are included in the flour. Modern machinery cleans wheat prior to milling with extreme thoroughness, and the separating machinery by which the flour is obtained free from the envelopes of the grain is also highly developed. The extent to which the outer parts of the endosperm are included in the flour is entirely under the miller's control.

In contrast to the old method of stone milling in which the object of the miller was to reduce the grain to one grade of flour in one milling operation, the modern system of gradual reduction produces in a long series of carefully-adjusted processes a series of products ranging from the finest white flour to dark reddish-brown flour (not mentioning grades of bran). When the whole flour product of the mill representing 72 per cent. of the wheat, i.e. practically all the endosperm of the grain, is taken together the product is known as Straight Flour. The lightest coloured grades, representing up to 36 per cent. of the flour derived from the middle of the grain, are known as Patents. The remainder, after taking out some of the finest flour as Patents and some of the lowest grades, is known as Clear Flour or under various other names.

Pékar's test. The colours of various flours are compared by means of Pékar's test. To carry out this test small heaps of flour are placed side by side on a narrow board, almost touching each other, or in small metal trays about $1\frac{1}{2}$ in. $\times \frac{3}{4}$ in. $\times \frac{1}{8}$ in. The flour is then pressed and smoothed off with a flour spatula. The contiguous surfaces are then examined in a north light. Slight differences in colour are made more apparent by immersing the samples carefully beneath water so that the surface of the

flour samples is wetted. On careful withdrawal from the water and exposure to the air, the differences in colour become accentuated. Still clearer indication of the relative colour values of the flour is obtained after drying the samples in a warm oven at 50° C., and examining the dried surfaces.

Ageing of flour. The colour of freshly manufactured flour improves by storage for some weeks after milling. This has been shown to be due to the bleaching action of the oxygen of the air. The oil contained in the freshly made flour is coloured, but on keeping the colour is gradually lost. The advantageous change which flour undergoes during the first few weeks of storage after manufacture is referred to as the 'ageing' of the flour. The practice of bleaching flour artificially arose out of the endeavour to achieve those advantages without lapse of time. The practice dates from 1901, when J. and S. Andrews patented a process for improving the quality of recently ground flour, semolina, and the like, by the use of a gaseous oxidizing agent such as chlorine or nitrogen peroxide.

The process licensed to millers under a royalty was extremely successful, and the patent rights became immensely valuable. An interesting account of the litigation which followed its introduction is to be found in H. E. Pott's *Chemical Patents*. The chief gaseous reagents used to-day in the bleaching of flour are chlorine and nitrogen peroxide. Other oxidizing agents in common use are nitrogen trichloride and benzoyl peroxide. Recently extensive investigation has taken place on the possible deleterious effects of such bleaching on the food value of bread made from bleached flour. Previous official researches made before the war on the same subject gave results of an entirely negative character. Results of the present investigation have not yet been published.

XVI

MAIZE

Production. The world's crop of maize is little inferior in quantity to that of wheat. Whereas the world's wheat crop amounted in 1925 to 502·1 million quarters, that of maize was 491·2 million quarters (Broomhall's figures). It ranks second in value of our imports in cereals, amounting in 1925 to 27·6 million cwt. worth £13·1 million, compared with wheat 97·7 million cwt. worth £68·5 million, and flour 9·1 million cwt. worth £8·3 million.

In approximate order of the magnitude of the crop, the chief countries of production are as given in the table herewith:

Production of Maize[1] *in the chief producing countries.*
In thousand quarters of 480 lb. per quarter.

	1913.	1922.	1923.	1924.	1925.
World's Total.	439,560	470,070	491,640	431,500	491,200
U.S.A.	285,500	337,200	356,350	269,820	(338,450)
Argentine	28,000	20,550	20,580	32,500	21,700
Brazil (av.)	17,500	21,300	23,600	18,340	?
Russia	8,600	9,490	9,970	8,030	20,500
Jugoslavia	(3,500)	16,400	9,890	17,430	(15,000)
Rumania	14,290	13,540	17,660	18,140	20,470
Italy	12,560	8,960	10,410	12,330	12,400
Hungary	24,620	5,680	5,750	8,650	10,790
Br. India	9,730	8,890	10,180	(10,000)	(10,000)
Union of S. Africa	3,340	5,050	6,250	4,000	8,540
Egypt	7,590	8,310	7,840	(8,000)	(8,000)

From these figures it will be seen that in 1925 the United States lead with a crop of 338·45 million quarters which was 3·9 times the size of her wheat harvest and 64 per cent. of the world's production. Almost the entire crop was consumed within the country. The world acreage under maize keeps steadily increasing. The main reasons for this increase are the high yield per acre obtainable from maize crops, averaging, for

[1] *The Corn Trade Year Book* (J. G. S. Broomhall, 1926), which omits Brazil.

instance, 35 bushels over the five central States of the middle-west of the United States, and its high food value for pig feeding.

For satisfactory development maize requires a long, hot summer, warm nights, and—unlike wheat—frequent summer rains. Without summer rains the crop cannot be raised, so that countries with dry summers, like Chile, California, and North Africa, are not suitable for maize, although the summer temperatures are sufficient.

The maize plant is a true cereal of the genus *Zea*, the main species of which are given as follows: *Z. tunicata*, or pod maize; *Z. everta*, the pop-corn, with a small oval-shaped grain pointed at each end; *Z. indurata*, or flint maize, with a hard oval-shaped grain; *Z. indentata*, or dent maize, characterized by a dent along the distal end of the grain; *Z. amylacea*, or soft maize; and *Z. saccharum*, or sweet maize.

Flint and dent maize are the varieties which come into commerce. The kernels of flint maize are entirely glassy and hard, and the grain has smooth contours as in Fig. 8, No. 2. The kernels of the dent maize are only glassy in areas adjacent to the sides, the germ lying in an area of starchy opaque endosperm which extends to the end of the grain distant from the germ. Where this softer starchy area reaches the surface cells of the grain it dries out and the surface becomes dented or wrinkled. The position of the germ, the starchy and the glassy areas are shown in the photograph (No. 18 of Fig. 8).

The plant varies enormously in size and habit. It usually grows to a height of from five to eight feet. The staminate flowers are borne at the top of the main axis where they form a 'tassel' and produce abundant pollen. The pistillate flowers from which the grain develops are borne on a spike in the axil of one of the lower leaves of the same plant. The spike is enveloped in a sheath or spathe. The pistillate flowers are arranged regularly round the spike in as many as twenty-four rows of thirty to fifty florets per row, each ripening to a single grain attached to the spike, forming when ripe the maize 'cob'. The long styles attached to each floret grow up under the spathe and hang from the top, forming the 'silks'. These receive the pollen from the male flowers.

Imports into the United Kingdom. Our imports of maize in

1924 were derived from the Argentine to the extent of 71 per cent. by weight of the total, from Rumania 7·3 per cent., from the United States 5·9 per cent., Russia 5·0 per cent., South Africa 3·6 per cent. Supplies also came from India, Australia, Canada, and Portuguese East Africa.

Imports of Maize into the United Kingdom from the chief countries of origin.

		1913.	1922.	1923.	1924.	1925.
Total	000 cwt.	49,155	37,200	34,490	37,667	27,585
Value	000 £	£13,770	£15,022	£14,252	£16,994	£13,078
Argentine	000 cwt.	38,854	12,839	19,798	26,835	16,780
Rumania		1,002	509	1,424	2,796	1,471
U.S.A.		6,879	14,746	5,330	2,225	152
Br. S. Africa		35	2,754	4,764	1,373	6,579
Port. E. Africa		—	208	929	647	357
Br. India		119	61	386	669	269
Russia		1,684	—	—	1,929	403
Canada		212	5,664	806	37	59
Australia		—	—	—	—	603

In some years maize also comes in smaller shipments from Spain, Italy, Brazil, Uruguay, and Kenya.

Commercial varieties. The commercial varieties of maize are distinguished by their origin, colour, and form. They are all varieties of *Zea indentata*, dent maize, or *Zea indurata*, flint maize.

Plate Maize.

(*a*) Cinquantino maize. A small maize of yellowish-orange colour, glassy. Its name is derived from the five facets into which the germ end of the grain is moulded. It is rather larger in size than the European cinquantino.

(*b*) Red Plate maize. A medium-sized flint maize, rounded, of bright orange colour.

(*c*) Yellow Plate maize. Similar to (*b*) but of yellow colour. It is largely mixed with the red varieties.

(*d*) White Plate maize.

Rumanian Maize.

(*a*) 'Danube maize'. This is a large round maize of light yellow colour.

(*b*) Gal-Fox maize. This is grown in the district between Galatz and Foxani. It is mainly yellow in colour, although it

contains also darker kernels as well as purple grain. The grain is of the large dent variety, rather rounded. It is smaller than Danube maize.

(*c*) Bessarabian maize. This is a small maize of pale yellow colour.

(*d*) Cinquantino maize. This is a very small maize of rather paler yellow colour than the corresponding Plate maize. The typical grain is rather long and the sides are flattened in five facets which narrow off to the germ end.

(*e*) Pignoletto maize is the fiery red variety of small maize.

Russian Maize.

(*a*) White maize. A medium-sized variety of round white flint maize (resembling white Plate maize), shipped from Novorossisk.

(*b*) White maize. A large maize of the flint variety, like Hickory King in appearance (shipped from Odessa).

(*c*) Yellow maize. A medium-sized variety of very pale yellow flint maize (shipped from Odessa).

(*d*) Large yellow dent maize.

Indian Maize.

(*a*) Calcutta Yellow maize. A small variety of pale yellow maize.

(*b*) Red Karachi maize. Very similar to red Plate maize.

(*c*) Bombay White maize. A small to medium-sized white flint maize.

South African Maize.

(*a*) F.A.Q. and grades of Hickory King, a white dent maize.

(*b*) Round yellow and flat yellow maize.

United States Maize.

The varieties exported to Europe are the large grained dent variety. The United States Grain Standards divide maize into three classes:

(*a*) White corn, of which at least 98 per cent. by weight of the kernels are white: a slight tinge of light straw colour or of pink on kernels otherwise white being admitted.

(*b*) Yellow corn, of which at least 95 per cent. by weight of the kernels are yellow: a slight tinge of red on kernels otherwise yellow being admitted.

(*c*) Mixed corn.

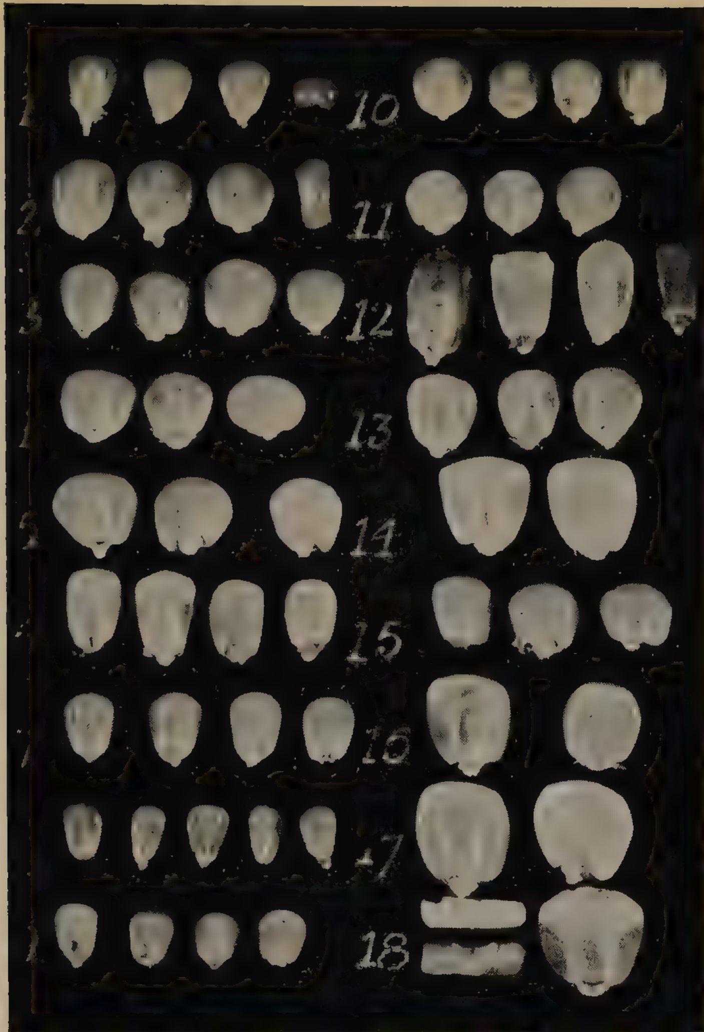

FIG. 8. TYPES OF MAIZE IMPORTED INTO THE UNITED KINGDOM

(About ¾ natural size)

1. Plate Cinquantino
2. Red Plate
3. Yellow Plate
4. White Plate
5. Danube
6. Gal-Fox
7. Bessarabian
8. Rumanian Cinquantino
9. Yellow Calcutta
10. Red Karachi
11. White Bombay
12. Queensland
13. Small White Russian
14. Large White Russian
15. Small Yellow Russian
16. Large Yellow Russian
17. South African Hickory King
18. Hickory King in cross section

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Australian Maize. (Queensland and N. S. W.)

A long, narrow, wedge-shaped, dent variety. It is multi-coloured, viz. yellow, orange, deep red, and white. The indented area is markedly yellow even in red grains.

Standards of quality. The standards against which maize is sold are: (1) the f.a.q. standards of the London Corn Trade Association made up as described in a previous chapter. Such standards are made for Plate, Danubian, and Indian maize. (2) Grades for South African maize. (3) Grades for the United States maize.

The criteria of quality for the grading of American maize are: (1) weight per bushel, (2) moisture content, (3) foreign material and cracked corn, (4) damaged corn. The schedule of requirements for each grade are as follows:

Grade No.	*Minimum test weight per Win. bushel.*	*Maximum limits of*			
		Moisture.	*Foreign material and cracked corn.*	*Damaged corn.*	
				Total.	*Heat damage.*
	Lb.	Pct.	Pct.	Pct.	Pct.
1	55	14·0	2	2	0·0
2	53	15·5	3	4	0·1
3	51	17·5	4	6	0·3
4	49	19·5	5	8	0·5
5	47	21·5	6	10	1·0
6	44	23·0	7	15	3·0

Maize in Grades Nos. 1 to 5 must be cool and sweet. The condition of Grade No. 6 may be musty or sour, but all graded maize must be cool.

If live weevil is present, this must be stated on the certificate.

The amount of foreign material and cracked corn is the percentage by weight of material which passes through a sieve with round holes 12/64ths of an inch in diameter, and all matter other than corn remaining on such a sieve after screening.

The most important single item in the grading of maize is the percentage moisture. This figure is invariably ascertained before a grade is assigned to a consignment.

Condition. Unless maize is quite dry it has no keeping qualities, and its condition as it arrives from overseas is often unsatisfactory. A condition for the successful cultivation of maize is dependable summer rains, and in consequence the crop is likely to be damp.

Maize is sold mainly on 'rye terms' (from the Plate and from the Danube), but also on tale quale terms (South Africa and the United States). Its sale on 'rye terms' involves the assessment of the damage due to its arrival out of condition.

When perfectly dry and in good condition the grain is bright, of good colour, and has a wholesome smell. When grain such as this is ground and extracted with alcohol as described in the footnote,[1] its acidity is usually below 20, and in perfectly sound grain may be as low as 12. As the grain gets older its acidity rises, but as long as it smells sweet the acidity remains below 25. Again, if the grain has been kept moist after harvest, its acidity increases and may be as high as 22 before shipment. It is then incipiently unsound, and although it may be dry before shipment and carry well, it is more liable to go out of condition than equally dry grain of lower acidity if conditions of moisture become unfavourable and it is stowed in proximity to ship's heat.

The next step is when the grain is still dry, bright, and of good colour, but has a sweet smell of malted grain. This condition is desirable, especially in certain maizes such as Cinquantino. If, however, the maize, while still exhibiting brightness and excellent colour, has a slight sour smell (only to be well recognized by comparison with a standard) it is going out of condition. The acidity figure then rises to 26 or 27.

The next stage is when the grain has a distinctly sour smell and its acidity is about 30.

After this its sourness increases and at the same time its colour and brightness are affected. As the grain becomes more and more damaged an increasing percentage of the kernels become darker in colour until they are dark brown; the brightness gives place to a dull exterior and the grain may be covered

[1] The acidity of grain is defined as the number of cubic centimetres of normal caustic potash (or soda) required to neutralize the acid present in 1,000 grm. of the grain. To make the estimation, a small part of the sample is ground in a hand-mill, 10 grm. weighed out, and left in 50 c.c. of alcohol (Sp. Gr. 0·86) for several hours in a stoppered flask. The mixture is then filtered, 25 c.c. of the clear extract taken and made up to 100 c.c. with distilled water. This is then titrated with N/100 alkali, using 1 c.c. of phenolphthalein indicator. A blank test must be carried out on the materials used. This test is of great use in determining condition analytically.

with a light powdery dust. This dust must be rubbed off the sample between the palms of the hand in comparing it with the standard, when some of its brightness is restored. When the acidity reaches 35–6 the grain begins to smell foul.

Standards of damaged maize are made up at intervals by the London Corn Trade Association for comparative purposes and the value of such a damaged standard is expressed as a definite percentage less than the value of the sound standard. Each variety must of course be compared against standards of its own kind.

The cause of the above-described condition, known as 'heating', is always the presence of an amount of moisture in the grain above 15 per cent. If sound maize is dry it cannot go out of condition even when it is subjected to considerable temperatures.

On the other hand, if it is moist, and especially if it is then kept in a warm place, it will begin to ferment and the temperature may rise to 150° F., producing all the above symptoms of damage. For reasons given on p. 145, the grain must have access to air in order to heat.

The heated maize is found in two positions in the hold: (*a*) either adjacent to ship's heat, in which case it may be deep down in the cargo, and sound grain may surround it; or (*b*) at the surface of the grain and for a few feet below. This fact brings into prominence a problem not sufficiently investigated. Efficient ventilation keeps a cargo cool and sweet; indeed the customary remedy for heated grain is to turn it over so that air has access and the grain is cooled. Yet without air grain cannot heat, even if it is damp (see p. 145). The heat-damaged part of the grain is always that to which air has easiest access (other conditions being equal). In practice the hold of a vessel is never air-tight, and could not be made so. Deep tanks in which grain is sometimes carried can be effectually closed.

Maize is frequently infested with weevil, and in this case a large quantity of 'frass' or broken dusty material eaten out by the grub contaminates the sample. To detect the presence of live weevil the sample is warmed for ten minutes or more and then sifted. The dust and the live weevils then pass through the sieve. The soft grubs remain in the maize.

The common admixture in maize consists of very light (and therefore bulky) scale, which is made up of the bracts at the

base of the kernel where it is attached to the cob. In addition to this there is often a considerable quantity of long threads known as 'silks', which are the stiles originally attached to the distal end of each kernel.

Composition of maize and its products. As a foodstuff 1 lb. of maize-meal yields 1,712 Calories per lb. as against oatmeal, say 1,880, barley-meal 1,607, and wheat-meal 1,639. It is remarkable for its high content of fat, viz. 4·2 per cent., and its low mineral (ash) content. In the partly milled form as polenta or maize grits, maize forms the staple cereal in certain Mediterranean countries. In the southern states of the United States it is widely used for human food in the form of succotash, or as a flat bread, or unripe as a vegetable sometimes cooked on the cob. Similarly in South Africa it is well esteemed as human food.

Its composition and that of some of its products is given by Plimmer as follows:

Maize.

	Water.	*Ash.*	*Fibre.*	*Protein.*	*Fat.*	*Carbo-hydrate.*	*Calories per lb.*
Grain	10·6	1·4	1·4	9·9	4·2	72·5	1709·6
Meal	9·6	0·7	0·3	9·9	2·1	77·4	1712·3
Hominy	11·2	0·4	0·4	7·0	0·5	80·5	1648·4
Cornflour	11·4	0·1	0·0	0·8	0·1	87·6	1648·4

A serious skin disease known as Pellagra sometimes attacks communities whose diet is mainly maize, and it is thought that the cause is the deficiency in the quality of the maize protein.

Products manufactured from maize. Maize forms the raw material for the manufacture of several important products, notably cornflour, maize oil, laundry starch, glucose, and maize gluten feeds. The nature of the protein in maize, the ease with which the germ which contains the oil is separated from the starch, and the minute size of the starch granules make maize an ideal material to split into its various constituents.

They all arise as separate products from one series of operations. The maize is steeped in hot water made slightly acid. It is then cracked in a mill and passed into a stream of water. The germs which contain the oil rise to the surface and are skimmed off. These are dried and pressed hot to obtain: (*a*) maize oil; and (*b*) a residue of gluten feed containing 20 per cent. protein. The oil is used mainly in the manufacture of soap.

The remainder of the grain in suspension in the water consists of starch, bran, and protein. The bran is separated on vibrating screens and is pressed, forming maize bran, a feed with 14 per cent. protein.

The starch milk is made to flow very gently over settling runs, where it is deposited and shovelled out from the runs. It is further purified by washing, dried, and then ground. This is cornflour. By slight variation in the final stages of manufacture it may be made into starch suitable for laundries, or for paste. The liquid from the settling runs passes into settling tanks where a residue is obtained from which a feed containing 40 per cent. of protein known as Maize Gluten Feed is derived by compressing.

Glucose is manufactured from maize starch. The starch suspended in cold water is run into a boiling dilute hydrochloric acid solution contained in a converter and heated under pressure for 15 minutes. By this operation the starch is hydrolysed, mainly to glucose. The product is run into vats, the acid neutralized with soda ash, and the neutralized solution evaporated. It is then thoroughly decolourized by repeated filtration through charcoal, and finally concentrated *in vacuo* to a perfectly clear colourless syrup.

XVII

BARLEY

THE world's production of barley amounts to rather more than one-third of that of wheat, showing an average of 173 million quarters of 400 lb. for the five years 1921–5. In 1913 Russia produced 31 per cent. of the world's crop, the United States 10 per cent., and Germany 10 per cent. In 1925 Russia still leads with 16 per cent., followed by the United States, British India, Germany, Canada, and Spain, in the order stated.

Barley has a wider geographical range than any other cereal, although for perfect maturation it requires a sunny harvest. Its cultural characteristics are as follows: it is sown as a late spring crop and it matures early, but the period of maturation is a distinct phase in its growth. It does best on well-drained light soils, in districts of low rainfall. On such areas it may yield better than either oats or wheat. Barley responds readily to the application of fertilizers. Nitrogenous fertilizers promote luxuriant growth of leaf and stem. Phosphates encourage root development and hasten ripening. Potash stimulates the development of the grain.

Barley is grown for its grain alone, the straw having little value. The larger part of the crop is fed to stock, the choicest is malted or used for human food. Perfectly grown samples of barley are highly valued for conversion into brewing malts, and great discrimination is exercised by buyers in judging their quality. The price paid for brewing barleys is quite in a class apart from that for feed. In consequence no cereal is more carefully grown and harvested than the best barleys.

Production. In England barley is grown mainly in the drier eastern counties of Norfolk, Suffolk, Lincoln, Rutland, Cambridge,

and East Yorkshire. The total acreage in England and Wales was 1,317,400 in 1925, and the average yield over ten years (1915–24) 30·1 bushels. This acreage has not declined as the wheat acreage has, mainly on account of the excellent quality of home-grown barley. The yield in Scotland is better, amounting to 35·6 bushels averaged over ten years, while in Ireland, where great attention has been paid to pure lines of seed and to the cultural requirements of the crop, the yield is 42·4 bushels. The highest average yield per acre is found in Belgium, where the figure reaches 46 bushels per acre, although the production is quite small.

Production of Barley.

In thousand quarters of 400 lb. of the chief barley-producing countries arranged in order of the size of the 1925 crop (Broomhall's figures).

	1913.	1923.	1924.	1925.
World Totals.	219,340	182,840	162,380	202,470
Russia	69,000	24,120	18,360	33,000
U.S.A.	21,400	23,780	21,400	26,160
British India	15,040	17,450	16,410	(17,000)
Germany	20,250	11,700	13,190	14,330
Canada	5,800	9,640	10,380	13,560
Spain	8,270	13,420	10,040	11,870
Japan	13,090	8,810	8,920	9,610
Poland	—	9,000	6,660	9,170
Gt. Britain and Ireland	8,200	6,850	7,000	7,200
Rumania	3,320	7,450	3,690	5,710
Algeria	6,350	5,630	2,240	5,320
Morocco	3,500	4,240	6,390	4,720
Denmark	3,300	3,900	4,100	4,190

Imports of barley into the United Kingdom. Our yearly imports of barley range between 800,000 and 1,000,000 tons. The figures for three recent years are given below, from which it appears that in 1924 the United States supplied 25 per cent., India 23 per cent., Canada 13·6 per cent., Chile 5 per cent., and Russia 5 per cent. of our requirements.

Imports of Barley into the United Kingdom.

For the years 1913, 1922, 1923, 1924, and 1925, showing the chief countries of origin arranged in order of the quantities exported in 1924. In thousand cwt.

	1913.	1922.	1923.	1924.	1925.
Total (quantity)	22,439	12,763	18,129	21,656	15,779
Value (£ millions)	£8·1	£6·1	£7,830	£12·1	£8,532
U.S.A.	4,438	5,921	6,228	5,496	5,582
British India	3,619	37	560	4,935	478
Canada	2,562	2,545	3,009	2,956	3,068
Russia	6,105	—	456	1,102	3,612
Chile	83	450	826	1,100	756
Iraq	—	676	1,388	983	89
Morocco	—	1	—	839	66
Denmark	520	461	191	756	196
Persia	26	53	831	691	55
Poland	—	—	1	459	49
Argentine	264	25	21	391	22
Czechoslovakia	—	202	379	448	291
Australia	3	371	797	343	345
Rumania	1,389	1,544	1,891	270	141
Tunis	349	31	639	162	315
Algeria	124	13	511	105	444

Other countries from which small supplies are derived are Sweden, Germany, Belgium, France, Austria, and Turkey.

Botanical classification of barley. Barley belongs to the genus *Hordeum*, and those cultivated are varieties of the species *Hordeum sativum*. The genus is distinguished among the grass family by the presence of one floret only in each spikelet, while, for example, in wheat there are usually three florets, and in oats two in each spikelet. These single-flowered spikelets of barley are arranged in threes on alternate sides of the notches up the rachis, and are attached to the rachis directly. Thus at each internode or notch three single-flowered spikelets are attached, which ripen to three barley grains, if all are fertile. When this is the case, six vertical rows of grain are developed, and the variety is known as six-rowed barley. In a second large group of barleys, namely, the two-rowed barleys, the two lateral spikelets of each set of three remain sterile, so that only the central spikelet on each side of the internode of the rachis develops into a barley-corn. Thus two-rowed barleys are produced.

These two main subdivisions are again split up according to the characteristic form of the ear. This may be long, lax, and narrow, nodding on maturity, or it may be shorter, denser, and broader, and on maturity remaining erect.

The following classes are thereby produced, and the names of common varieties are added.

Classification of Barley.

Six-rowed barleys.

Hordeum polystichum.

Hordeum hexastichum	(Very dense eared)	Many winter barleys and foreign brewing barleys, e.g. Chilian brewing
Hordeum parallelum	(Dense eared)	Foreign brewing barleys
Hordeum vulgare	(Lax eared)	Scotch bere. Californian, Argentine, North African, and Black Sea Barleys

Two-rowed barleys.

Hordeum distichum.

Hordeum zeocrithum	(Very dense eared)	Spratt and hybrids therefrom
Hordeum erectum	(Dense eared)	Goldthorpe; Plumage Archer; Archer; Spratt Archer
Hordeum nutans	(Lax eared)	Chevallier

A mixture of two-rowed and six-rowed barleys is common in foreign barleys.

Description of the barley grain. As with cultivated oats the grain as it is met with in samples is enveloped in its flowering glumes or paleae, and at the proximal end a fracture indicates the point of separation of the grain from the rachis when the grain was threshed. The flowering glumes invest the grain closely and cannot be detached without special care. The outer palea, that, namely, which covers the dorsal or germ side of the grain, is continued at the distal end in the shape of a brittle awn or beard, from 7 to 10 in. in length, which is broken off in threshing. The inner palea, that which covers the ventral or furrow side of the grain, is enfolded along its edges by the outer palea. The glumes and the paleae are modified leaves. They are veined and this is clearly seen on the palea covering the dorsal side, which has five parallel veins forming ridges which run from end to end of the grain. At the base of the inner palea lying in the groove caused by the furrow a small hairy bristle or rachilla is attached.

Discrimination between a sample from two-rowed barley and one from six-rowed barley is simply effected from the shape of the grain. The grains in six-rowed barley are crowded in threes

on one side of each internode of the rachis, with the result that the two lateral ones on each side of the flattened rachis become twisted while the central grain grows straight. Thus in a sample of six-rowed barley there will be one laterally symmetrical grain to two twisted grains. The twist is easily recognized, particularly when the grains are placed on the bench furrow side uppermost. The twist of the grains is then very obvious, as the photograph in Fig. 9 indicates, in No. 9, for example.

In two-rowed barleys only one grain on each side of the spike develops, namely, the central one of the group of three. In consequence it has room to develop freely, so that it grows perfectly symmetrically about a plane through the furrow.

Chevallier is a plump, uniform, and beautifully coloured barley of medium size (1,000-corn weight, 40 grammes). The rachilla is long and covered with quite short hairs. The base of the grain where it was attached to the rachis has a characteristic bevelled appearance, slightly triangular in shape. This barley is of the nodding, narrow-eared variety, that is, the distance of the grain up the rachis is greater than in Goldthorpe and Archer. There should be from six to seven notches per inch along the rachis. The malting quality of Chevallier as judged by the total nitrogen content and by actual malting comparisons is consistently inferior to Archer and Goldthorpe.[1]

Goldthorpe is a large grain variety (1,000-corn weight, 42 grammes). The rachilla is short and covered with bushy hairs. The base of the grain on the dorsal side has a characteristic transverse indentation visible even without the use of a lens.[1]

Archer is a small grained variety (1,000-corn weight, 39 grammes). The rachilla is long, and is provided with long hairs at the tip. The colour of the sample is not so good as that of Chevallier or Goldthorpe, but the quality as judged by the nitrogen content (average 1·56 per cent.) is consistently superior to all other varieties. Plumage-Archer and Spratt-Archer are two new hybrids of great economic importance.[1]

[1] *The Barley Crop*, 1926, Herbert Hunter, D.Sc., Ch. IV, 'Quality in Malting Barley'. See also A. J. Brown, *Laboratory Studies for Brewing Students*, 1904.

Fig. 9. BARLEYS AND OATS IN COMMERCE

(About $\frac{3}{4}$ natural size)

BARLEYS

1. Californian Chevalier
2. Californian Brewing
3. Californian Bright Feed
4. Australian Chevalier
5. Indian Barley
6. Canadian No. 4
7. Chilian Chevalier
8. Chilian Forage
9. North African
10. Goldthorpe (English)
11. Dan/Bess/Kusteridge
12. S. Russian (Odessa)

OATS

1. Canadian
2. Red and White Plate, Clipped
3. Dan/Bess/Kusteridge
4. New Zealand Gartons
5. N. Z. Sparrowbill
6. Chilian Stormkings

Designation of commercial barleys.

Home-grown barley is named according to the county in which it is grown. The chief varieties grown as brewing barleys are Plumage-Archer, Spratt-Archer, and Goldthorpe. Six-rowed barley when grown is utilized chiefly for feeding.

American barleys. From California: Californian brewing barley, Californian Chevallier, grades of Bright Feed, and Dark Feed barley. From other States: 48 lb. malting barley and feed grades Nos. 1, 2, 3, 4 set up by the respective Chambers of Commerce.

Indian barleys. Named after ports of shipment, viz.: Karachi, Bombay, and Calcutta barley. For feed and brewing.

Canadian barley. Nos. 1, 2, 3, and 4, feed. Rarely Nos. 1 and 2, extra Ontario; and Ontario on sample.

Russian barley. Feed barley named after the ports of shipment on the Black Sea: Odessa, Nikolaieff, Theodosia. Hence the term 'Black Sea barley'.

Chilian barley. Chilian forage and Chilian Chevallier.

North African barley. Named after shipping ports, viz.: Casablanca and Safi in Morocco, Oran and Algiers in Algeria, Tunis and Sousse in Tunis.

Denmark. Danish Island barley.

Polish barley from Reval and Stettin, sold on sample for malting purposes.

Persian barley, and Persian White barley from Mohammerah.

Australian barley. Australian Chevallier, Cape and Spratt barley.

Syrian barley. Ouchac barley from Tripoli. Hama barley. Gaza barley.

Turkish barley. Smyrna (Yerli) barley.

Rumanian barley. Mainly described as Dan/Bess/Kustendje barley. Orzoica is a high-grade brewing barley rarely exported.

Quality of barley. Feed barley is sold on grade from Canada and the United States. The main point deciding the grade is the weight per bushel. In Canada the grades are defined under the Canadian Grain Act, each definition covering a description of the condition and a natural weight qualification.

Thus No. 1 barley shall be plump, bright, sound, clean, and free from other grain, and weigh not less than 48 lb. to the bushel.

No. 2 barley shall be reasonably clean and sound, but not bright and plump enough to be graded as No. 1, and shall be reasonably free from other grain, and weigh not less than 48 lb. to the bushel.

No. 3 extra barley shall be in all respects the same as No. 2 barley, except in weight and colour, weighing not less than 47 lb. to the bushel.

No. 4 barley shall include all barley weighing less than 45 lb. to the bushel.

In addition to this there is a grade known as Feed and/or Rejected, and in some years additional grades as the crop requires, such as Nos. 1 and 2 extra Ontario.

No Federal grades for barley have yet been promulgated in the United States on account of the great difficulty in standardizing the fine points upon which the quality of the best barleys are judged. The grades adopted in the American Trade in barley have not the authority of the Federal Government as those of wheat, oats, maize, and rye have, but are set up by local authorities and are not uniform as between one centre and another. F.a.q. standards are made up in London for Australian, Black Sea, Chilian, East Indian, and Scandinavian barleys, all of which are sold either f.a.q. or on sample.

Malting barley. Barley intended for brewers' malt is sold on sample, and very great care is exercised in judging its quality. The process of malting consists in promoting the growth of the barley for a period of from nine to thirteen days so as to bring about biochemical changes in the composition and structure of the grain. When the requisite modification has been effected, the growing grain is allowed to wither by withholding water, and the change to malt is completed by drying the germinated grain on a kiln at a temperature of between 150° and 200° F.

The effect of the malting process is to dissolve the delicate cell walls within the grain which imprison the starch granules. The dissolution is brought about by a ferment (*cytase*) and this opens the way to the attack of the cell contents, namely, the starch and protein, by other ferments secreted mainly at the germ end of the grain. At the stage in the malting process when germination is arrested by drying, this attack has already begun. Part of the insoluble starch of the barley has been converted into soluble carbohydrates, namely, malt sugar and dextrin, and part of the

protein into soluble nitrogenous compounds. The change is completed in the mashing process, and when the malt is milled and extracted with hot water, about 70 per cent. of its weight is ultimately brought into solution, chiefly by the action of the ferment *diastase*, producing a sweet fermentable liquid. Barley for distilling purposes is malted for a longer period, namely, twenty days or more. In this case the malt is required not so much for its soluble extract as for its diastase. This ferment is developed in great strength when the grain is grown for a long period and not subsequently heated to a high temperature. The ferment is capable of converting starch into malt sugar. In consequence a malt with a high diastatic power may be used to convert a large quantity of starch from unmalted barley or from maize or potatoes into fermentable sugar. Smaller-grained imported sun-dried six-rowed barley is mainly used for this purpose.

The bearing of these processes on the requirements of barley for malting purposes will now be considered. It is clearly desirable: (1) that the barley shall germinate easily; (2) that the germination shall be uniform throughout so that every grain is at the same stage of growth at a given time; and (3) that the resulting malt shall yield a high proportion of soluble substances, particularly malt sugar, in order that the yield of beer shall be high; at the same time it is undesirable that the proteins shall be rendered soluble to any great extent. Experience has shown that these requirements may be judged well by a skilled man from the external and internal appearance of the barley from which the malt is to be made. The points of quality may be grouped under three headings: (*a*) the degree of maturation of the grain; (*b*) its uniformity; and (*c*) its condition.

Maturation. Barley which has been perfectly favoured by the season reveals this in the appearance of its skin or enveloping paleae. In the first place the skin is very thin, and has a very pale straw colour. It is bright and unstained, and shows delicate wrinkles running transversely round the grain. These characteristics indicate that no large part of the plants' energy has gone in developing the paleae but that their reserves of food have been transferred to the grain itself during the favourable period of maturation. Next, the grain should be plump, and on cutting it through, the endosperm should be seen to be mealy. This is an important indication of the favourable nature

of the development of the grain in the period just prior to harvesting. The mealiness is due to a high carbohydrate content and a corresponding low protein content, i. e. less than 1·5 per cent. nitrogen.

The infilling of carbohydrate into the grain is the last stage in the plants' development. The protein matter on the other hand is formed in the grain at an earlier period, so that any hindering factor such as lack of sun and cold weather in the period of maturation of the grain leads to a comparatively high protein (e. g. 1·7 per cent. nitrogen) content in the grain and a correspondingly low carbohydrate figure. The endosperm of the grain is then hard and flinty. Difficulty is encountered in malting such barley, for it requires a higher temperature to induce growth and a corresponding loss is entailed in weight of the malt formed. 100 parts of Chevallier barley yield 89 parts of malt.

As in wheat the mealiness of a barley grain becomes more pronounced as the grain approaches the dead ripe stage. Small air spaces then occur between the cells composing the endosperm, which leads to a falling off in the specific gravity of the mealy grain. In consequence the determination of the specific gravity of the grain gives a measure of its mealiness. To determine this 50 grammes of the grain are placed in a 100 c.c. flask and toluene is run in from a burette up to the 100 c.c. mark. The volume of the 50 grammes taken is then equal to the volume of toluene run in. From this the density of the grain is obtained by division of the number representing the weight in grammes of the barley taken by the number representing the volume in cubic centimetres. Toluene is used in this experiment because it does not wet the grains and leaves no air spaces round them.

Several instruments have been designed to enable the examination of the mealiness of a sample of malting barley to be carried out readily. Fifty grains may be cut in two transversely in an instrument, similar to that in Fig. 10, called a Kornprüfer or farinator, and the texture of the endosperm examined. A similar instrument may be obtained by means of which the grain may be cut through longitudinally. This allows the embryo to be examined. A further instrument, known as a diaphanoscope, enables the observer to get an idea of the nature of the endosperm without cutting the grain through. The grains are placed

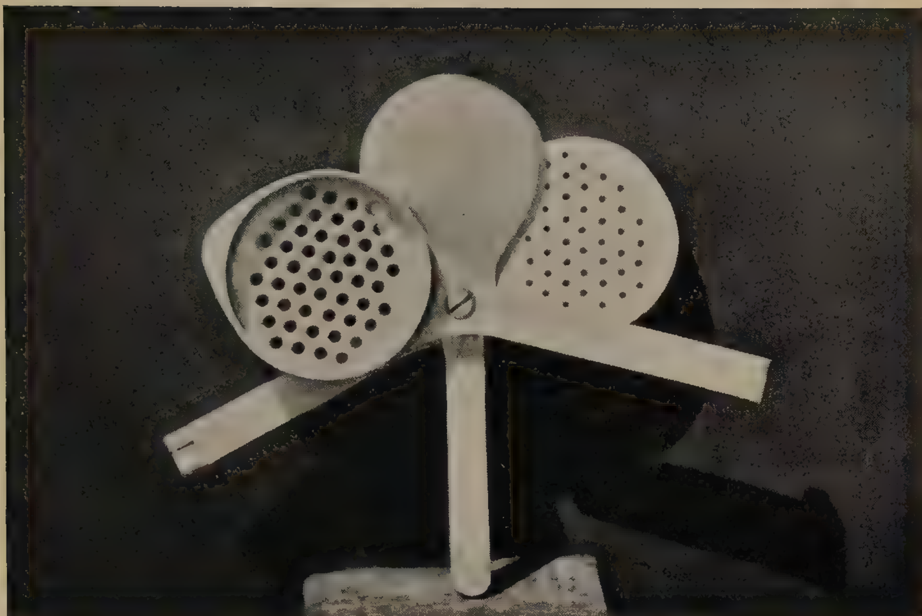

FIG. 10. THE KORNPRÜFER OR FARINATOR

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close together on a ground glass plate which is illuminated from beneath so as to allow the light to penetrate the grain. A difficulty which arises in this examination is that barley-corns with a purplish pigment appear much darker than those which are colourless, and this may lead to an assumption that they are more mealy. Mature grains, as judged by the above characteristics, are more easily converted into malt, and on account of this larger percentage of starch and the nature of their proteins, yield a larger quantity of soluble extract. Home-grown barleys yield 75 per cent. of soluble material. Californian and Smyrna barleys yield 70–73 per cent., and North African 65 per cent. and upwards.

Uniformity. Since the malting process depends on changes during growth, it is important that all the grains should be of the same size. The size is expressed by the weight of 1,000 grains. This varies from 39–48 grammes. The larger grains yield the larger percentage extract and, other things being equal, are preferred. If the grain is not uniform in size the changes will not have proceeded far enough in the largest grains when the smallest will be overgrown. Uniformity of colour of the sample is also looked for.

Condition. The barley grain must have the sweet smell of dry, sound grain. A high moisture content leads rapidly to a falling off in the germinating power of the grain. It is important that there should be no injury to the grain. Such injury may be mechanical, brought about by thrashing or by handling, or it may be that the grain has already sprouted at some time due to rain. The germ end of the grain should therefore be examined for sign of such damage. Damaged grain and broken kernels may easily become the centres of fungal growth on the malting floor.

Weight per bushel. The weight per bushel is not the criterion of quality of malting barley that it is of the quality of wheat. The appearance and condition of the sample are of much greater importance, and a barley of a lighter natural weight may be better for malting purposes than a heavier one. Analytically the nitrogen content of the grain is the surest guide to malting quality. Form No. 70 of the London Corn Trade Association lays down rules for sampling barley in cases where the natural weight is guaranteed in the contract, and sets up a schedule of

allowances in respect of the difference in natural weight guaranteed by the contract and that found by the Association.

When the natural weight is guaranteed at the port of shipment 1 per cent. is allowed off this weight for decrease during the voyage.

In this connexion it is interesting to note that, unlike wheat, barley does not invariably show a decrease in natural weight as the moisture content rises. This is because the grain is sometimes loosely invested by the paleae, leaving air spaces between the kernel and the husk. The additional amount of moisture may easily cause the kernel to swell without causing an increase in the volume of the individual grain. The additional moisture may thus bring about an addition to the natural weight.

Vitality of the grain. Since the malting process consists in the modification of the contents of the grain by controlled germination, it is of supreme importance that the grain should grow easily and uniformly. To test the germinating capacity 100 grains may be counted out and placed on moist sand in a suitable dish covered to prevent evaporation and kept at 60° F. Each day those grains which have germinated are removed, and in this way the rate and uniformity of germination may be gauged and the percentage which remain idle noted. English malting barley will germinate to within 4 per cent., while many foreign sun-dried barleys will show 100 per cent. germination. Many forms of germinator are designed for this test, the commonest in use being Coldewe's.

Kiln-dried barley. To promote uniformity and ease of growth of malting barley, the grain is often artificially matured by kiln-drying. This is carried out at a temperature not above 105° F., either on a malt kiln or in a drying drum which is rotated while the hot gases from the kiln are drawn through with a fan. After such sweating the grain contains from 10–12 per cent. moisture. Its effects are similar to those of natural maturation in a favourable barley season. Not only does the grain germinate more readily and evenly, but the resulting malts are more satisfactory in quality. Home-grown grain may contain up to 20 per cent. moisture, and unless kiln-dried and then kept for some weeks prior to steeping it fails to germinate satisfactorily.

XVIII

OATS

THE world crop of oats is about half that of wheat. It is grown mainly as food for horses, both the grain and the straw being utilized, a very large part of the crop never leaving the farm. A small proportion of the grain (less than 5 per cent.) is utilized as human food, mainly as porridge.

The United States leads in size of crop, producing in 1925 32·1 per cent. of the world's total. Russia is second with 15·0 per cent., then Canada with 10·9 per cent., and Germany 8·3 per cent. The figures for the chief producing countries of the world are given in this table herewith:

Production of Oats.[1]

By countries in the chief producing countries in the order of the size of the 1925 harvest, in thousand quarters of 320 lb. per quarter.

	1913.	1922.	1923.	1924.	1925.
World's total.	484,630	390,330	437,050	421,470	466,580
U.S.A.	112,180	121,550	129,980	152,270	150,190
Russia	125,500	53,330	53,930	51,300	70,000
Canada	43,000	49,120	56,400	41,100	51,300
Germany	66,780	27,660	42,000	42,170	38,470
France	35,630	29,450	33,630	30,550	33,030
Poland	—	17,230	24,800	16,620	23,780
Gt. Britain and Ireland	19,790	19,730	19,620	20,190	19,500
Sweden	9,640	7,900	6,680	7,440	8,450
Argentine	5,090	5,650	8,150	5,400	8,490
Czechoslovakia	—	7,140	9,480	8,300	8,060

Description of the grain. The grains (Fig. 9) are contained in a spikelet (refer to Fig. 2, B), borne on a fine stem or pedicle, containing one, two, or more kernels, each enveloped by two 'husks', or flowering paleae. The whole of the florets within the spikelet are enveloped by two thin, membranous, veined glumes, one of which slightly overlaps the other and protects the

[1] Broomhall's *Corn Trade Year Book*, 1926.

florets from which the grains develop. The uppermost floret frequently remains undeveloped. The membranous glumes are sometimes present in a hand sample. (Fig. 9, No. 6, Oats.)

Examining the spikelet more closely it is seen that the successive grains arise from a short axis which grows out from the ventral surface (furrow side of the grain) of the base of the lower grain. In the usually cultivated forms of oat the grains of the spikelet remain attached to each other so that in hand samples one is often seen apparently growing from another. In wild oats the grains fall apart on ripening.

The single grain in a hand sample is seen to be enveloped, as above described, by two 'husks', which in most cultivated oats are smooth and free from hairs. In wild oats the husks are usually covered with long hairs from the base up. The kernel lies free within these husks, although they closely embrace it, the outer palea enfolding the edges of the inner. (In barley, by contrast, the paleae are grown on to the kernel, and the kernel can only be separated from the husk by milling.)

The outer husk (that, namely, on the dorsal side of the grain) has five thin veins, the middle one of which may be extended in the form of an awn. In wild forms this awn is bent and twisted below the bend, and is borne on all the grains in the spikelet. In cultivated forms it is only borne on the lowest grain and then is reduced in size: or it may be absent entirely.

Classification of species.[1] The oat plant belongs to the genus *avena*, of which there are eight common species, viz.: *A. nuda*, *A. sterilis*, *A. fatua*, *A. brevis*, *A. strigosa*, *A. abyssinica*, *A. sativa*, *A. sativa orientalis*. Oats are suited to temperate and moist climates, and those cultivated in such districts are almost exclusively varieties of the species *Avena sativa*, or its nearly allied form *Avena sativa orientalis*, commonly called 'side oats'. In the main they are sown as spring crops to fill in the rotation on the farm and to provide for horses and young stock.

The species *A. sterilis*, better suited to hotter climates, is grown in countries bordering on the Mediterranean, in California, and Australia. The species *A. fatua* is the weed common in all temperate countries. *A. strigosa*, a hardy spring form, is cultivated in the Shetlands and in certain districts in Wales where the higher yielding varieties fail.

[1] *Oats*, Herbert Hunter, D.Sc., 1924.

The remaining species are of no commercial importance, except for the possibility of breeding from them. Thus *A. nuda*, the Naked Oat of China, was used as one parent by Messrs. Garton Limited, in raising the variety Sir Douglas Haig.

The above-named species are distinguished from each other by small structural differences as follows: in all oats except *A. nuda* each kernel remains enclosed in the two enveloping husks or paleae. In *A. sterilis* and *A. fatua* the grain on ripening becomes detached and falls away naturally from the plant, whereas in the species commonly cultivated (*A. sativa* and *A. sativa orientalis*) the grains remain attached to the panicle and must be separated from it and each other, when there is more than one grain in the spikelet, by a distinct fracture.

The habit of shedding its grain, useful in a wild plant, is a drawback in a cultivated plant, and cultivation has brought about the condition in which the grain remains on the plant. Similarly the wild wheats become detached naturally from the plant. The point of fracture from the rachilla is distinctly visible at the base of the grain of the commonly cultivated oats.

Commercial varieties. The oats met with in commerce in London are as follows: Home-grown and Irish oats, Canadian, American, Argentine, Baltic, Rumanian, and New Zealand oats. The following figures indicate the extent of the trade in imported oats:

Imports of Oats into the United Kingdom.

(000 *omitted.*)

	1913.	1922.	1923.	1924.	1925.
Total	18,163	9,357	9,759	10,316	8,366
Value	£5,672	£4,363	£4,143	£4,317	£3,708
	000 cwt.	000 cwt.	000 cwt.	000 cwt.	000 cwt.
Canada	2,348	3,329	3,002	3,002	2,991
Argentine	6,402	2,165	3,362	3,527	1,297
U.S.A.	1,434	2,958	1,721	2,000	2,178
Irish Free State	—	—	511	531	865
Chile	—	265	311	752	571
Russia	2,785	1·6	82	120	16
Latvia	—	137	152	111	5
Germany	3,422	—	0·4	7	175
Sweden	—	216	14	4	1

Small quantities are also derived from the Netherlands, Rumania, and New Zealand.

For trade purposes oats are classed according to their colour and their country of origin. The colour referred to is not that of the inner kernel, which does not vary, but that of the enveloping husk or paleae. Oats may be white, yellow, red, grey, black, or mixed, yellow being included in the term 'white' in American oats.

Weight per bushel. Weight per bushel is the main criterion of the commercial quality of imported oats. Thus Canadian, United States, and Australasian oats are sold on grade, and the main factor in the grading of oats in these countries is the weight per bushel. Again, Plate oats, Black Sea oats, and Baltic oats are sold commonly with a guarantee of natural weight. Form 69 of the London Corn Trade Association sets out a scale of allowances in respect of deficiencies in natural weight of oats between that found on arrival and that guaranteed by contract. One per cent. is allowed off the natural weight guaranteed at the time of shipment 'for decrease in natural weight during the voyage', except for shipments from North Russian ports. Presumably this decrease is due to absorption of moisture on the journey. Beyond this, stated allowances are made for each pound deficiency:

'When the guarantee is 40 lb. English per bushel (or its equivalent) or more, and the ascertained weight is less than 40 lb., an allowance to be made on the basis of 3*d.* per lb. deficient weight. When the guarantee is less than 40 lb. any ascertained deficiency to be allowed for on the basis of 1½*d.* deficient weight. When the guarantee is over 40 lb. and the ascertained weight does not fall below 40 lb., any ascertained deficiency to be allowed for on the basis of 1½*d.* per lb. deficient weight.'

Standards of quality. F.a.q. standards are made by the London Corn Trade Association in respect of the following commercial classes of oats:

Country of Origin.	*Designation of Standard.*
Argentine	Buenos Aires Group, clipped and unclipped Bahia Blanca, clipped and unclipped
Chile	Chilian Stormkings. Mixed, coloured and/or Tawny/Black/White
Russia and Rumania	Black Sea Oats
North Africa	Tunisian, Algerian Oats, Cape Oats

The following standards made abroad are adopted by the London Corn Trade Association:

Country of Origin.	*Designation of Standard.*
Canada	Nos. 2 and 3 Canadian Western. Nos. 1 and 2 Canadian Feed
Tasmania	'A' Grade Giant White. F.a.q. Giant White. 'A' Grade Stout White. 'A' and 'A 1' Grade Algerian
New Zealand	A, Super A, and Super B Grades Gartons from Canterbury, Christchurch, and Invercargill. Sparrowbill oats, A, B, and C Grades

American oats. The grade requirements for American oats relate to the condition and general appearance (including the moisture content), the weight per bushel, and the purity of the grain. The schedule is as follows:

Oats.

Grade requirements for white, red, grey, black, mixed, bleached, and clipped oats.

Grade.	*Condition and general appearance.**	*Minimum test weight per bushel*	*Sound cultivated oats not less than—*	*Heat damaged (oats or other grains).*	*Foreign material.*	*Wild oats.*	*Other colours, cultivated and wild oats.*
				Not to exceed—			
		Lb.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
1†	Shall be cool and sweet and of good colour	32	98	0.1	2	2	2‡
2	Shall be cool and sweet, and may be slightly stained	29	95	0.3	2	3	5§
3	Shall be cool and sweet, and may be stained or slightly weathered	26	90	1.0	3	5	10
4	Shall be cool, and may be musty, weathered, or badly stained	23	80	6.0	5	10	10

Sample grade. Shall be white, red, grey, black, mixed, bleached, or clipped oats, respectively, which do not come within the requirements of any of the Grades from No. 1 to No. 4, inclusive, or which have any commercially objectionable foreign odour, or are heating, hot, sour, infested with live weevils or other insects injurious to stored grain, or are otherwise of distinctly low quality.

* The percentage of moisture in Grades Nos. 1, 2, and 3 shall not exceed $14\frac{1}{2}$, and in Grade No. 4 shall not exceed 16.

† In the case of white oats, No. 1 shall be cool and sweet and of good white or creamy white colour.

‡ Four per cent. of other colours allowed in No. 1 red, grey, or black oats. This column does not apply to mixed oats.

§ Ten per cent. of other colours allowed in No. 2 red, grey, or black oats.

The weight per bushel is taken without removing foreign material.

The percentage of the marketed crop of white and red oats which reaches Grade 1 is invariably small, usually less than 5 per cent., but a much higher percentage of the other classes commonly reach Grade 1 requirements.

Condition. The condition of a sample of oats depends on the presence or absence of fungal disease in the crop, on the harvest weather, the storage conditions, and the subsequent treatment of the grain. It is judged largely by the brightness and smell of the sample, which are affected adversely by the common causes of ill condition. Thus an excess of moisture in the grain while still cool may lead to sprouted, stained, and dull grain, and while in store, to heated or musty grain. A change in the pleasant smell of dry grain is then easily recognized. Unripened grain remains greenish in colour.

Oats suffer severely from the two fungal diseases, rust and smut. Crown rust, *Puccinia coronata*, and black stem rust, *Puccinia graminis*, both take heavy toll of the oat crop. Their effect is seen in the sample by its undeveloped appearance and light weight. No remedy other than breeding rust-resistant varieties is available for abolishing this damage. Loose smut (*Ustilago avenae*) fills the grain with the loose black spores of the fungus so that the panicle appears covered in soot. It may thus show in the sample. Covered smut of oats (*Ustilago kolleri*), in which the spores do not escape from the husk of the grain, is much rarer. Pickling the seed with formalin or copper sulphate (5 lb. of copper sulphate in 50 gallons of water, or 1 lb. of commercial formalin in 40 gallons of water) is an effective remedy against smut. The damage to the crop in England and Wales is estimated at 2 to 5 per cent. and this is also about the extent of the damage in America. Occasionally a field may be very badly damaged by the development of smut. Thus a field in Norfolk was reported in 1920 as damaged to the extent of 50 per cent.

Weevilled oats are not common, presumably because oats are mainly raised in cool, moist countries. In this country frit-fly is a serious pest of spring grown oats.

On account of the importance attached to brightness in judging the condition of a sample, oats are sometimes bleached with

sulphur dioxide which readily brightens the colour of the husk, and it also effectively prevents mustiness. A sample of oats bleached by sulphur dioxide can be shown to be treated by passing a stream of hydrogen generated in a flask from zinc and hydrochloric acid into a solution of lead acetate, then adding the oats to the flask containing the acid. Sulphured oats cause a blackening of the lead acetate, on account of the formation of black lead sulphide. Oats are sometimes passed through a machine which clips off the awn and the ends of the husks: such oats are designated Clipped Oats. Clipping raises the weight per bushel considerably and does not affect the feeding value of the oats adversely, although it may reduce the germination when carelessly done.

Taint. Oatmeal and rolled oats, like wheaten flour, readily absorb foreign odours. The commonest form of this damage is met with in imported oats products in the form of taint by apples. Comparison against a sound standard of the same variety is absolutely necessary to establish slight damage by taint. A useful method of comparison is to fill two wide-mouthed bottles fitted with double-bored corks, one with the sample to be tested and the other with the standard, and to place them in a warm position. A current of warm air from an aspirator is then driven gently through the contents of each by means of a glass tube which passes through the cork almost to the bottom of the bottle. The air then escapes through a second glass tube passing through the second hole in the cork. The air issuing from the two samples is then smelt. A very slight 'taint' may be detected in this manner.

Inherent quality of oats and oat products. The quality of oats depends entirely on its food value. The chief factors determining the food value are as follows: (*a*) the proportion of husk to kernel; (*b*) the composition of the kernel in terms of protein, fat, carbohydrate, and ash.

These two factors decide the food value per lb., but from the farmer's point of view, both as grower and consumer, the third factor determining food value per acre in conjunction with (*a*) and (*b*), viz. (*c*), yield of grain and straw per acre, is the most important.

(*a*) The ripened oat husk is of very little value, and is used for packing, or may be burnt. It may be ground and then finds its way into feed, into compound cattle or poultry foods, or it may

be used to adulterate barley-meal and middlings.[1] In consequence, oats with a small percentage of husk are preferred to those with a thick husk. Professor Berry classed home-grown oats as thin-husked when there was 25 per cent. and under, medium-husked up to 27 per cent., and thick-husked above 27 per cent. of husk.

Thin-husked varieties occur in oats of each colour, viz. white, yellow, black, and grey, the lowest percentage of husk being found in black and grey winter oats.

(*b*) The composition of the kernel determines the food value per lb. of the grain. Oats are rich in oil, protein, and minerals. Modern successful varieties of oats are good yielders, but they are less rich in oil and protein than older varieties which give a smaller crop. The wild oat may contain almost 13 per cent. of oil in the kernel, but modern oats frequently contain no more than 7 or 8 per cent. Below is given the average analysis of four older varieties (indifferent yielders) compared with a modern variety which crops well, the[2] figures being on the dry kernel:

	Earlier varieties.	*Later varieties.*
Protein	16·70	14·39
Oil	10·08	6·87
Carbohydrates	68·60	75·23
Fibre	2·10	1·48
Ash	2·46	2·10
Calorie value per lb. dry kernel	1955 C.	1896 C.

Modern varieties of oats, such as Abundance, are characterized by larger and better filled grain than older varieties, but the grain is more starchy and less rich in oil and protein. (This appears to be paralleled by the higher starch and lower protein contents of the soft European wheats which are all good yielders.)

Yellow oats contain less protein than either white or black and grey grain. On the other hand oats richest in protein are found among white oats with *thick* husks.

The influence of wet, sunless weather on the composition of oats was observed during the contrasted seasons of 1920 (wet) and 1921 (very dry) to lead to a decrease in protein, oil, fibre, and husk, and an increase in carbohydrate.

[1] T. W. Fagan, *Oats; their milling and by-products.*

[2] H. Hunter, *Oats*, 1924.

Hunter has pointed out that although modern varieties of oats have an analysis less rich in protein and oil, their superior yields in lb. of grain per acre outweigh the deficiency. Thus the produce from a variety with a protein content of 10·79 per cent. and a yield of dry grain of 2,249 lb. per acre will contain 23 lb. more protein than that of another with 11·34 per cent. protein yielding only 1,937 lb.

The detailed discussion of the composition of oats in Chapter VI of Hunter's volume on Oats mentioned on p. 126, should be consulted.

Milled products.[1] Kiln-dried oats are husked, stone milled, and rolled, producing a range of milled products and offals. These are rolled oats, oat-meal in various 'cuts', oat-flour, meal seeds (or light oats), oat husks, oat, and scree dust.

The shape of the oat grain may be small, short, and well filled, as in the Potato Oat, which is favoured for milling purposes, or large, broad and well filled, as in Abundance. A long narrow tapering oat (Grey Winter) is less liked. For milling purposes the oat should be sound, well filled, and thin husked, and the sample should show high uniformity in size of grain. If this latter point is not observed the kiln-drying process produces a waste of the lighter grains and a difficulty in removing the husks.

The oats are first passed through cleaning machinery consisting of sieves, cockle cylinders, and aspirators to remove foreign material and weed seeds. They are then kiln-dried for from $2\frac{1}{2}$ to 3 hours by being spread to a depth of from 6 to 8 in. over a perforated floor and dried by air at from 250° to 260° F. from an open fire. Alternatively, a special kiln for continuous drying is employed. By the drying process the moisture content is reduced from an average of 13 per cent. to an average of 2·3 per cent. In this dry condition the oats are easily 'shelled', the milling process is facilitated, and the oatmeal keeps better. They are then stored for a few days. To remove the husks the dried oats are fed into a stone mill and the product separated by air currents into light fluffy material known as scree dust (4·5 per cent. by weight), husks (17·4 per cent.), and oat kernels. Alternatively the shelling may be effected by the passage of the dried oats through pairs of emery-faced discs, placed with their axes horizontal, one of which revolves while the other remains

[1] See T. W. Fagan, loc. cit.

stationary. The product is separated as before into scree dust, husk, and kernel. The kernels are then scoured by being passed through encased cylinders in which beaters revolve. By this operation a small quantity of oat dust is removed and the kernels, free from husk and dust, are ready for grinding.

The grinding takes place in stone mills constructed of French Burr stones and the product is sifted through metal screens into Round, Medium, or Fine Oatmeal, according to the mesh. The part retained by the sieves, termed Meal Seeds, consists mainly of the broken grains of small oats. It amounts to 4·5 per cent of the product.

Oat-flour is produced from medium cut oatmeal by milling between steel rollers and separating the product finally over silk bolting cloth. Rolled oats are made from the whole kernel which is first steamed and passed through smooth rolls and subsequently steam-dried.

The composition of the various oat products is given by Fagan as follows:

	Moisture.	*Oil.*	*Protein.*	*Fibre.*	*Ash.*	*Carbo-hydrate.*
Round oatmeal	8·36	8·72	14·27	1·79	1·44	65·15
Medium oatmeal	8·26	8·68	14·12	1·53	1·83	65·58
Fine oatmeal	8·68	9·37	13·96	1·23	1·77	65·03
Rolled oats	8·34	8·07	15·04	1·18	1·60	65·77
Rolled oats	8·5	6·5	13·1	0·7	—	69·5
Oat-flour	8·7	8·68	15·01	0·85	1·22	65·54
Oat husks	6·32	1·36	2·57	32·91	3·87	52·97
Scree dust	7·4	4·30	9·7	26·00	5·00	47·00
Oat dust	8·5	9·2	10·6	19·7	4·8	47·2
Meal seeds	8·0	1·9	5·6	25·30	2·6	45·50

Freshly manufactured oatmeal contains a little over 3 per cent. of moisture. Consequently a bag of 280 lb. of freshly ground oatmeal absorbs moisture from the air, and this takes place at the rate of about 1 lb. per day for the first week and then less per day until it has gained about 14 lb. in weight.

As regards yield, figures as high as 60·7 per cent. of meal are given. But Fagan states that average working represents a yield of 55·5 per cent. meal, requiring 12 bushels of grain at 42 lb. per bushel to yield a sack of 280 lb. of meal.

XIX

PESTS OF GRAIN AND FLOUR

Fungal pests.[1] The conditions under which wild plants flourish are competitive. A wild plant dominates a particular district because its structure, habit, and requirements are better adapted to the natural surroundings than those of possible competitors. Careful observation shows that species are in constant competition with each other and continuously give ground to or take it from more or less successful rivals.

When species are cultivated, conditions are made artificially favourable for them. Chosen seed is carefully sown on prepared and specially fertilized ground. One countervailing disadvantage is that this care to produce healthy and abundant crops in orderly formation also opens the way to more formidable attacks of disease. In the case of cereals, fungi are a menace from the time of germination of the seed, during the period of growth, at the time of flowering, right up to the formation and maturity of the grain.

Storage of grain is again an artificial state, and although cereals are of all foodstuffs the most suitable to store and are the least susceptible to damage on storage, yet specific insects find the best condition for their existence in stored grain. Stored grain is attacked in certain conditions by small beetles (the weevils) and minute spiders (mites); and flour may be infected with mites, moths, and their caterpillars.

Fungi. The fungi with which we are concerned are microscopic plants which live parasitically in the tissues of the growing crop and pass the winter in the fields on autumn-sown crops or in the harvested seed or straw.

Fungi commence life from spores which are single minute cells containing protoplasm and oil. The fungus of smutted wheat, for instance, fills the grain with from six to nine million dark

[1] *Fungus diseases of Crops.* Ministry of Agriculture, Miscellaneous Publications, No. 38. 1922.

brown spores. Such spores are extremely light and may be carried by the wind from plant to plant. When a fungal spore alights on a suitable medium it grows out into a long tube, frequently branching. Such a tube is referred to as a hypha. The hyphae interlace and entirely penetrate the medium. The mass of interlacing hyphae which are then visible to the eye is known as the mycelium of the fungus.

The parasite derives its nourishment from its surroundings. Thus when a fungus penetrates a leaf it grows between the cell walls and enters the cells, absorbing the contents of the cells and using the food for its own growth. Having established itself it bursts the epidermis of the plant and produces spores which in many cases are borne on the wind to neighbouring plants; but sometimes the infection is not wind-borne. Each kind of fungus produces a specific appearance of damage to the plant, and the attack is usually restricted to certain parts only of the plant. Thus, rust attacks the leaves and stems and produces rusty patches on the leaves or small black streaks on the stems. Again the fungi are specific in their attacks. The wheat rusts are fairly confined to wheat; the barley rusts to barley; the oat smut to oats, and so on.

Smut.

Bunt or stinking smut (*Tilletia tritici* and *T. laevis*) is a fungus which is frequently met with in samples of wheat. Each infected grain is rather rounder, shorter, and more pointed than the sound grain, but otherwise looks normal. It easily breaks when pressed, and a dust of dark brown resting spores escapes. These have the odour of decaying fish. When bunt is present in a sample, even to a small extent, it taints it with its fishy smell, and broken smut balls contaminate the sample with the dust. The infected grains are very light and are separated from the sound grain by aspiration. Infection of the plant takes place in the seedling stage. Spores are present on the surface of sound seed from a smutted lot of wheat, and when this is sown the spores germinate. The germinated spore produces thread-like basidio-spores from which grow out other infective spores called conidia. These penetrate the germinating seedling and are carried up into the ear as the plant develops. They complete their life history when the ear is ripening by producing a dense mass of interlacing hyphae

within the ripening grain. The hyphae then divide into millions of separate spores which round themselves off and become dark in colour.

Loose smut of wheat (*Ustilago tritici*) is not common in England, whereas bunt is. In the hand sample the fungus appears as round, black smut balls, which break up into powder and dust the grain. The life history of this smut is very similar to that of bunt, but this disease may also be carried to the plant at flowering time and infect the ovary through the stigma.

Smut also attacks oats, barley, and maize. Loose smut (*Ustilago avenae*) is common on oats (p. 130) and covered smut rare. On barley covered smut (*Ustilago hordei*) is common, and loose smut rare.

By the term 'covered' is meant that the spores are enclosed in the grain and not immediately visible in a hand sample, or on the spike. In loose smut the spike and the sample are blackened.

On maize the fungus attacks all parts of the plant.

The treatment of seed grain by first cleaning it by aspiration and then soaking it for from 2 to 3 hours in formalin solution (1 lb., 40 per cent.) in 40 gallons of water or in copper sulphate solution (5 lb. to 50 gallons of water) is effective in eliminating smut. Where this precaution is not taken the rate of increase in the disease may be formidable.

Rusts.

This group of highly specialized fungi is widespread over the plant kingdom. Rusts do not appear in the harvested grain, although they seriously diminish the yield and the quality as measured by the weight per bushel. No means of disinfecting the seed or of combating the attack is known. The annual damage to cereal crops by rust is very great and is stated to be equal to one-third of the world's yield. Nitrogenous manures favour the development of rust. Rust often exhibits the striking characteristic of passing one part of its life cycle on a grass (a cereal for instance) and completing it on another flowering plant, alternating from one to the other. The host plants are usually specific to the particular species of rust.

Black rust (*Puccinia graminis*), the most serious of the rusts, passes the summer and winter on the wheat plant or on oats,

barley, or rye, and the spring on the common barberry. Farmers have known for centuries that barberry bushes growing in the hedges by wheat fields are a menace to the wheat crop, and in most civilized countries their gradual suppression has been effected. Black rust is extremely rare in the British Isles, but still occurs in parts of South Wales, where barberry bushes still grow in the hedgerows. In the United States black rust became serious again in recent years and a campaign was started in 1919 to destroy the shrub. The partial failure of the 1925 crop of Argentine wheat was due to this fungus. The botanical explanation of the part played by the barberry in spreading the disease is due to de Bary, who worked out the life history of *Puccinia graminis* in 1865. The fungus passes the winter on the straw of the cereal, where it produces short black streaks. On cutting a section through the infected straw these streaks are seen to be due to clusters of thick-walled club-shaped double-celled spores called teleutospores borne at the ends of the hyphae and bursting through the epidermis of the straw. In spring the teleutospores germinate and produce minute conidia which are borne on the wind. If they alight on a barberry leaf they penetrate it and form reddish yellow pustules called aecidia. The pustules burst and chains of aecidiospores are liberated in succession from them. The aecidiospores are then carried by the wind to the growing wheat plantlets where they infect the leaves and stems, upon which alone they can germinate. They penetrate the leaf and after establishing themselves by their hyphae they produce the familiar rusty patches. The appearance of these patches is due to masses of orange-coloured uredospores which again are windborne to neighbouring wheat plants. Thus throughout the late spring and summer they spread through the crop from leaf to leaf.

Towards the end of the summer, as the crop should be filling out, the black teleutospores already described begin to appear in place of the orange-coloured summer spores. The appearance of these black spores gives the name to the fungus—black rust. The life cycle is now complete, the next stage being the production of aecidia on the barberry.

Yellow rust. The common rust to which wheat is subject in England is another species of Puccinia, namely *P. glumarum* (Yellow or Spring Rust), which produces yellow patches on the leaves of wheat in spring and early summer, reaching its height

in May and June. The life cycle of this rust is not so complex as that of *P. graminis*. It overwinters on autumn-sown wheat, and perhaps also on wild grasses, and produces a succession of uredospores. It is for resistance against this rust that Little Joss was bred: Yeoman, Swedish Iron, and Rivet wheat are also resistant. As previously mentioned, breeding for variety resistance to rust is the only known means of countering the disease.

Summer or brown rust (*P. triticini*) attacks wheat in England later in the year.

Rusts also attack barley, oats, and rye. Crown rust of oats (*P. coronata*) produces a golden yellow colour in the leaves, and the fungus overwinters on winter-sown oats.

Brown rust (*P. simplex*) is the common barley rust.

Ergot (*Claviceps purpurea*).

This is a common fungal disease of rye, and it may attack wheat. In the place of the rye grains long slightly curved dark violet bodies, called sclerotia, twice or thrice as long as the grain, project from the chaff up the spike. They contain a large percentage of fat and a poisonous alkaloid which has a marked pharmacological action on the human body. When the crop is ripe the sclerotia fall to the ground, where they pass the winter. In late spring they produce outgrowths of complex structure, from which minute filiform spores are liberated. These are windborne and infect the flowers of the crop. Here the spores form a mycelium and abstrict conidia. The conidia are extruded in a sweet fluid, called Honey Dew, produced by the fungus. This is sought by insects, and in this way the infected conidia are carried from flower to flower. The food brought up to the developing ovaries is used up by the fungus in forming the sclerotium, which consists of a dense mass of fungal hyphae.

In countries where rye is the staple cereal, especially in outlying districts, this fungus may become a great danger to the community.

XX

PESTS OF STORED GRAIN[1]

Weevils. The chief insect pests present in samples of grain are the weevils, of which three kinds are met with: *Calandria granaria*, the grain weevil, which never flies; *Calandria oryzae*, the rice weevil, which has perfect wings, but which does not fly; and *Rhizopertha dominica*, which can and does fly.

Three days after mating the female weevil lays eggs at the rate of twenty eggs in twenty-four hours, laying in all up to 400 eggs, after which she dies. Each egg is deposited in a minute puncture which she makes in the pericarp of the grain. The egg takes three days to hatch at ordinary temperatures. The egg develops into a small soft larva which feeds on the endosperm of the grain, growing in size until it undergoes the change into the mature beetle. Thus the damage to the grain is brought about not only by the mature weevil but by the larvae. The mature weevil then escapes from the grain. The period that elapses from the egg to the adult varies according to the temperature. The average period is 45 days, but warm weather shortens this period and cold weather lengthens it to 124 days, the increase being due to the longer larval period.

The temperature at which the rice weevil, *C. oryzae*, multiplies fastest is 82° F. An increase of 700 fold in 16 weeks at this temperature is mentioned in Report 7 referred to below. Below 65° F. this weevil does not multiply, and the adult does not survive our winter.

C. granaria, the grain weevil, multiplies rapidly at 80° F., although its rate of multiplication is not so great as that of the rice weevil. It is not so susceptible to cold and the adults survive our winter.

Rhizopertha dominica is a pest which requires still hotter conditions for development and is very susceptible to cold. Consequently it is not a menace to stored wheat in this country.

[1] See *Grain Pests*, (War) Committee of the Royal Society, Reports 1–10. 1919-21.

The moisture requirements of weevils are not considerable. Yet if the wheat is very dry it is immune from weevil attack. Thus Indian wheat, which is most frequently attacked by weevil, remains free from the pest 'if sundried and stored in a dry building'. Experiments conducted by Dendy and Elkington showed that the rice weevil died off in wheat the moisture content of which was 9·7 per cent., the grain weevil lived on with difficulty but did not multiply, and the *Rhizopertha* were rather reduced in numbers. These results were obtained after 79 days. In wheat containing 6·1 per cent. moisture, only *Rhizopertha* lived on, and then in decreasing numbers. In these experiments the wheat was not allowed to become moist from the excretions of the weevils. Moist wheat is more favourable to the general growth of weevils than dry. The faecal matter which the weevils excrete absorbs moisture from the air and thus the whole becomes moister. This may be an important factor in the 'heating' of a given lot of grain, which, as pointed out elsewhere, is due to high moisture content. The presence of the weevils leads to a rapid shrinkage of weight in the grain in summer time and a marked drop in the weight per bushel.

The flour-moth (*Ephestia Kühniella*). The caterpillar of this moth is the commonest pest of flour and of milled products generally. The moth is pale greyish brown, tame, not often flying. After mating the female lays from 124 to 300 eggs, which become dark yellow, and in about a fortnight the small caterpillars appear. These feed greedily, fouling the flour with their faeces and spinning a thread as they go, and increasing greatly in size. After a period of weeks, and in cold weather of months, the caterpillar spins a cocoon. Within the cocoon it passes through the pupal stage and emerges as a moth. At 82° F. the development from egg to moth takes a month, but at ordinary temperatures the change is very much slower.

The caterpillars of another species, *Ephestia elutella*, form a web over the surface of stored grain in their wanderings over it. This produces the phenomenon of 'webbing' of stored grain, especially in the dark. The web formed may be thick and strong. The caterpillars damage the grain by consuming the germ, such damage being confined to a depth of about one foot of the bulked grain.

Mites. Both wheat and flour may be damaged by mites, the

chief pest being *Aleurobius farinae.* Moisture is absolutely necessary for the life processes of this insect. The precise percentage of moisture has been carefully determined (Report 2 of the Royal Society's Grain Pests Committee). In no instance was commercial wheat found to be infected when its moisture content was less than 13 per cent.

When wheats with varying moisture contents were infected experimentally with mites, it was shown that with a moisture content of 13 per cent. their multiplication was rapid, at 12·4 per cent. slow, and at 12·2 per cent. death occurred. A temperature of between 65° and 75° is most favourable, but above these temperatures the mites are killed. The presence of this pest, as of weevils, increases the moisture content of the whole, since excretions of the mites absorb moisture from the air.

Mites damage wheat directly by feeding on the germ. Their presence is detected by their unpleasant smell, and by sifting and examining the siftings with a lens. In flour in which the presence of mites is suspected the surface is smoothed with a flour spatula and then left for some time, after which it is examined with a lens, when the workings of the insects are seen. The insect is minute, measuring only 0·75 mm. Its life history is as follows: In suitably moist surroundings the female scatters twenty or thirty eggs measuring 0·12 mm. by 0·08 mm. at the rate of three or four per day. They are white and smooth. After three or four days the larva is hatched, and feeds and grows rapidly for three days, after which it remains inert. It then casts its skin and becomes an immature nymph, in which state it remains for from six to eight days, after which the adult six-legged spider-like insect is formed. The life cycle in summer takes seventeen days and in winter twenty-eight days.

Manitoba wheat appears to be most infected, but the source of the infection has not been determined. The Dominion Government entomologists state that the grain is free from mites on shipment. Mites have not been observed on wheat from tropical countries.

Experimental work on the damage to flour by mites showed that a No. 14 silk (140 meshes per inch) removed the adults and that the flour was satisfactory for prompt commercial use. Its quality judged by its gluten, acidity, and by baking tests revealed no deterioration.

XXI

STORAGE CONDITIONS

DRY grain requires hardly any precautions to keep it sound for long periods, and it is thus the ideal foodstuff to store and handle. Kept dry, wheat even retains its capacity to germinate over a series of years, only losing it gradually. Thus dry wheat which has been kept ten years may contain a small percentage of live grain, but only in rare instances will grain still older retain its capacity to germinate.

Nevertheless, grain, like any other foodstuff, contains locked up energy which in the right circumstances may be set free. Further, it is a living seed, not dead inert matter, and is continually breathing and may easily be brought to ferment. It contains carbohydrates, protein, and fat, and these substances may become degraded, giving out heat in the process.

The symptoms of normal and harmless change are the loss of germinating capacity and a very small change in total weight. The symptoms of abnormal change are rise in temperature, change in appearance, smell, and taste of the grain, and considerable loss in total weight. When the latter changes set in the grain is said to be going out of condition, or 'heating'. The main cause determining change of this sort is the presence of more than a certain allowable maximum of moisture in the grain; accessory factors are the temperature at which the grain is stored, the length of time it is stored, and the access or otherwise of air.

A second form of damage may take place on long storage, namely damage by weevils and, in milled products, by the caterpillar of the grain moth, which may do great damage in a short time. Here again the main cause determining damage by insects is the presence of moisture above an allowable maximum, and the extent of the damage is governed by the temperature of storage, length of time in store, and the access of air.

Loss of weight by breathing. While grain is living it continuously absorbs oxygen from the air, which oxidizes a small

part of its organic material, and gives out a corresponding weight of carbon dioxide, thereby deriving the necessary energy to keep it alive. In consequence, when grain is stored so that free access and circulation of fresh air is prevented, the atmosphere becomes charged with carbon dioxide. While the grain is dry the weight of carbon dioxide evolved is extremely small.

Thus Elkington found that 500 grammes of Manitoba wheat containing 10·2 per cent. moisture gave out only 33 mg. of carbon dioxide in 157 days at room temperature. This is equivalent to a loss of weight due to carbon dioxide of only 0·007 per cent. over the whole period at 30° C. In thirty-one days 100 grammes of English wheat with a moisture content of 15·6 per cent. gave 19 mg. of carbon dioxide. The loss of weight due to such normal respiration in sound wheat is therefore entirely negligible.

Spontaneous heating. As the moisture content of the grain increases the rate of evolution of carbon dioxide increases regularly but slightly up to the point at which storage of the grain is known generally to be safe, viz. about 15 per cent., but varying for the particular grain. Above this safety figure a new fermentative change sets in, and carbon dioxide is produced in much greater quantity. Thus sound wheat containing 17 per cent. of moisture gives out about twenty times as much carbon dioxide as the same weight of wheat containing 11 per cent. in the same length of time. Such fermentation is accompanied by the liberation of heat. If this heat cannot escape, as when the bulk is large, the grain 'heats' spontaneously. Once the temperature has begun to rise the fermentative change producing the rise is accelerated by the increase in temperature it produces, for chemical changes are hastened by an increase in temperature. Consequently the damage spreads at a cumulative rate. As the wheat heats it darkens, becomes soft, and gives off large quantities of carbon dioxide and moisture and loses weight correspondingly. The shrinkage in weight begins to be considerable as soon as the grain starts to go out of condition, and at the same time the moisture content rises.

Influence of external temperature on spontaneous heating. As long as the air temperature is low, as in an English winter, the danger of the spontaneous fermentation of stored wheat is very small, but the growth of moulds will occur if the wheat is damp, even although the storage temperature is low. It is when

the temperature outside is high and the moisture content of the grain is above 15·5 per cent. that heating arises. It is then only a matter of time before the grain will begin to go out of condition unless vigorous, through ventilation is possible. If the grain is dry and remains dry it can be safely stored, no matter what the atmospheric temperature.

Access of air. When grain heats through the presence of excessive moisture it is invariably that part of the bulk exposed to the air which becomes damaged, and the damage decreases deeper down in the bulk. Thus, in the experimental work of Duvel and Duval on maize containing 17 to 18 per cent. of moisture stored in a silo, the temperature just below the surface rose to 133° F., while at a depth of seven feet the temperature was 40·9° F. The oxygen of the air is used by the fermenting grain in producing carbon dioxide. On board ship damage by spontaneous heating of moist grain occurs in two positions: (1) at the surface of the cargo and just below where air has access; or (2) at any point adjacent to ship's heat. Except in rare instances, heating of grain on board ship is due to the unsatisfactory state of the grain on loading. While it is true that dry grain will not go out of condition even if it is subject to ship's heat, nevertheless the influence of such external heat may cause grain, which in a cool position might just have been carried successfully, to arrive in a heating condition, and this appears to be particularly true of maize.

The fact that air is necessary for the oxidation involved in the chemical changes which cause grain to heat suggests that if grain were stored in an air-tight container it could not heat even if it were damp. To store damp wheat in this way is of course a theoretical proposal, but it is one which has been tested in the laboratory.[1] Wheat containing 20·7 per cent. of moisture was kept at 28° C. in an incubator in two thermos flasks, one air-tight and the other open to the air. The temperature in the air-tight flask remained practically constant at 28° C., while the temperature in the open flask rose in seven days to 43° C. The temperature then fell slightly, then rose again and reached a second maximum of 49° C. after twenty-three days. 'In the sealed flask the wheat, though very damp, looked bright and clean, and with the exception of one or two grains at the bottom of the flask was

[1] *Report* No. 5 *of the Grain Pests Committee*, of the Royal Society.

quite free from mould or mildew. It was only slightly caked and had an acid smell. The heated wheat in the ventilated flask presented a marked contrast. It had a very musty smell, was badly caked, mouldy on the surface, rotten and black in the lower layers, and very damp.'

Air-tight storage. The practice of storing dry wheat in air-tight pits or buildings has long been common in countries where the wheat is naturally dry (e. g. Malta, India). Such storage has the advantage that it sterilizes the grain, for weevils succumb to air-tight storage. This was in doubt until the exhaustive researches of the Grain Pests War Committee of the Royal Society showed conclusively that grain insects sealed up in air-tight vessels succumb as soon as the oxygen has been used up.

The theoretical position is, then, that wheat stored in air-tight containers can neither heat nor become damaged by insects.

In practice wheat is not stored either in granaries, silos, or on board ship in air-tight structures, but instead the moisture content is reduced until storage with access of air is safe for periods of months. To effect this reduction in moisture content drying machinery is available at storage points. The position then becomes this, that with ordinary access of air, heating is a matter of time except in dry climates. To guard against heating the grain is run out periodically from the silo and carried along the bands so that it may dry and cool.

At one time storage with provision for continuous through ventilation was extensively practiced and was apparently very successful. Thus Dinglinger's granary (1768), which provided for a thorough and continuous draught of air to pass through the heaps of grain, had a great reputation. Sinclair's granary (1805) made a similar provision for through ventilation. It appears that by this method wheat is prevented from heating and is not attacked by weevil.[1]

If national granaries in which surpluses accumulated from years of good harvests were contemplated there is little doubt that the system to be adopted would be air-tight storage of dry grain. The advantages of such storage are summed up by the authors of Report 6 of the Grain Pests Committee of the Royal Society as follows:

[1] J. F. Hoffmann, *Die Getreidespeicher.*

'(1) It sterilizes the grain by destroying insects in all stages, or other vermin which may be present.

(2) It prevents, absolutely, the access of insects and other vermin.

(3) It prevents even grain with a high moisture content from becoming mildewed, as we have shown by experiments not described in these reports.

(4) It prevents even grain with a high moisture content from heating (but it does not prevent the development of acidity, due presumably to anaerobic fermentation, if the moisture content is excessive).

(5) It prevents the absorption of moisture from the atmosphere, so that grain if stored dry will remain dry.

(6) It saves labour and expense by doing away with the necessity for turning the grain over or running it from one silo into another in order to prevent heating.'

If a sufficient stock of wheat could be accumulated in the various countries of the world to provide for the needs of the people for a protracted period it is likely that the price of wheat could be maintained at a steady level, since supplies would then be largely independent of immediate harvest prospects in the great producing countries.

Control of insect pests. The problem of combating the various insect pests which attack grain and flour has received great attention. There are two methods in use: (1) fumigation with prussic acid; and (2) heating the grain or the mill to 140° F.

(1) *Hydrocyanic acid.* Of all the fumigants proposed for flour moth, hydrocyanic acid gas (prussic acid) is the only effective agent which does not harm the flour. Sulphur dioxide is also effective, but ruins the flour, as is well known. It may, however, be used where cereals other than wheat are concerned. Hydrocyanic acid gas is a very powerful poison, and consequently the disinfecting of a mill with this effective substance must be carried out under expert supervision. One per cent. by volume of the gas kills moths, larvae, and eggs in a period of from twelve to eighteen hours. The older method of producing the gas by the action of acid on sodium cyanide in pots distributed throughout the mill has now been superceded by the use of the gas itself absorbed in Kieselguhr (a product known under the name Zyklon) or of the gas liquefied in cylinders. Disinfecting with prussic acid for the destruction of weevil is in practice much less successful.

(2) *Heat.* Common insect pests of grain and flour cannot withstand a temperature of 140° F. In consequence, if a mill is

provided with sufficient central heating to enable this temperature to be maintained over the week-end, the pests can be eliminated.

The method adopted during the war to salvage the badly weevilled Australian wheat was first to seal the bulk wheat and to pump in carbon dioxide. This gas is not an insecticide, but the insect becomes inert in it. Its ravages could consequently be checked until the grain could be sterilized. This was effected by passing it through a sterilizer in which it was subject to a temperature of 140° F. maintained by steam coils for a period of a few minutes. After delivery from the sterilizer, it was screened again and subjected to aspiration.

XXII

FOOD VALUE OF CEREALS

CEREAL grains and the products milled from them acquire their value in the main from their suitability as foodstuffs for man and animals. Considerations of quality based upon weight per bushel, freedom from admixture, condition, and in the case of wheat, on bakehouse behaviour, are in consequence of secondary importance: the main consideration is the nutritive value of the cereal to man or animal. This problem is entirely a scientific one. In one or two instances it has practical commercial significance, e. g. in the case of feeding stuffs sold on analysis and wheat sold on protein content. Otherwise the food value of the substance is taken for granted and does not enter into commercial transactions, or only indirectly so. The food value of a substance is determined: (*a*) by its chemical composition; (*b*) the extent to which it is digested and usefully employed in the body; and (*c*) by the presence or absence of 'accessory food factors' in the substance.

A percentage analysis of a typical wheaten flour is as follows:

	Per cent.
Moisture	15·0
Carbohydrate	72·4
Fibre	0·2
Fat	1·25
Protein	10·75
Ash	0·4

Moisture. The moisture supplies no energy to the body although it is essential to the vital changes which are continuously going on within the body. Thus, the adult requirements of water, either contained in foodstuffs or in drink, amount to $4\frac{1}{2}$ pints daily, but the water does not supply energy.

Ash. The ash consists of mineral salts derived from the soil by the plant. Again, although the body requires a small amount of these constituents, they supply no energy. The energy is derived from the carbohydrate, fat, and protein, which are the

combustible substances contained in the foodstuff. The energy they afford is measured by the amount of heat they give out when they are burnt.

Carbohydrates. The carbohydrates are an important group of organic substances which include starch, sugar, and fibre. When one ounce of any one of these three chemical substances is burnt, the quantity of heat given out as they are oxidized to carbon dioxide and water amounts to 116 Calories. This is also the amount of heat which the same weight of starch or sugar gives out when it is completely digested in the human body, for the same chemical changes take place in each case. Fibre cannot be digested in the human body, although horses and cattle digest it, and when completely digested it yields the same amount of energy as the same weight of starch or sugar.

Fats. Fats again are a source of energy. Where one ounce of fat is completely burnt to carbon dioxide and water it yields 263 calories. Each unit of fat thus supplies $\frac{263}{112} = 2{\cdot}3$ times as much heat as a unit of carbohydrates.

Proteins. The proteins are also a source of energy. But whereas fats and carbohydrates are burnt away completely in the body to incombustible substances (carbon dioxide and water), the proteins are not entirely oxidized by animals but are only partly so. Their unburnt component passes away in the urine. Allowing for this, one ounce of protein, when completely digested, is taken as yielding the same amount of heat energy as the same weight of carbohydrate, viz. 116 Calories. There is, however, a great distinction to be drawn between the function of the carbohydrates and fats and that of the proteins. The two former supply heat which is convertible into work, but the protein does more; it not only supplies heat but it is also the source from which the flesh of the body is derived. In consequence the value of a foodstuff is determined (1) by the heat energy in Calories available from the food, and (2) by the percentage of digestible protein present in it which may be used to replace wasted body tissue.

The requirements in these respects of the adult man (weighing eleven stones) have been arrived at in various ways and may be

[1] The Calorie is the amount of heat required to raise one kilogram of water through 1° C.

taken as approximately 2,800 Calories per day, as far as energy is concerned; the protein requirement is about three ounces daily, yielding about 12 per cent. of the 2,800 Calories. These figures are for a man following a sedentary occupation.

The consumption of a pound loaf (16 ounces) with the following analysis: carbohydrate 47·9 per cent.; protein 7·2 per cent.; fat 0·9 per cent. yields, when fully digested,

$$\{(0{\cdot}479 + 0{\cdot}072)116 + (0{\cdot}009 \times 263)\} \times 16 \text{ Calories}$$

$\doteq$ 1,060 Calories. The weight of protein contained in the loaf is $0{\cdot}072 \times 16$ oz. $= 1{\cdot}15$ oz.

The requirements of an adult in energy and protein would appear therefore to be entirely satisfied by the consumption of about $2\frac{3}{4}$ lb. of bread per day: but this states the problem of food values too crudely. The proteins of the various substances used for food are only *similar* in chemical composition and constitution, and not identical. It thus comes about that for health it is desirable to obtain ones protein ration from a variety of sources in order to supply to the body the necessary range of slightly different protein substances out of which it may build the protein peculiar to itself.

Vitamins. The problem of deciding the appropriate ration of food is not, however, solved by considerations based alone on the chemical composition of foodstuffs and the energy to be derived from them. Research has shown that illness and death result from the deficiency in foodstuffs of certain reactive substances which have been named vitamins, even when the food is in sufficient quantity amply to satisfy energy and protein requirements. The quantity of vitamins present in a foodstuff known to be rich in them from its power of curing disease brought about experimentally on animals fed with artificial foods, is extremely minute. No vitamin has yet been isolated. Yet by experiments with animals it has been conclusively shown that to nourish the animal body completely, food must contain at least four kinds of vitamins or accessory food factors. These have been named vitamins *A*, *B*, *C*, *D*, and work is proceeding on vitamins *E* and *F*. The entire absence of any one of these vitamins from a diet brings about specific pathological symptoms in the subject. Thus a complete absence of vitamin *A* arrests growth, brings about disease of the eye, and diminishes the power of resistance to

diseases of the respiratory tract. Vitamin *B* has been named the anti-neuritic factor since its absence is followed by polyneuritis (in pigeons) and beri-beri. The disease of scurvy follows the absence of the anti-scorbutic factor, vitamin *C*. Vitamin *D* has been shown to control bone formation, and is known as the anti-rachitic factor. Further research has indicated the existence of other factors *E*, *F*, of the functions of which little is known with certainty. Vitamin *B* is most stable towards heat, and vitamin *D* is probably equally stable: then comes *A*, the least stable being vitamin *C*, but this statement must not be too generally applied, since the stability is determined also by the acidity of the medium.

White wheaten flour, pure cornflour, and polished rice contain no vitamins at all. Wheat germ is rich in vitamin *B*, less rich in *A*, and free from *C*. The brans of wheat and maize are fairly rich in vitamine *B*, and free from *A* and *C*. Germinated pulses or cereals contain all four vitamins, being fairly rich in vitamins *B* and *C*.

It is mainly on account of this new knowledge concerning vitamins, their absence from white flour and their presence in the germ and bran of wheat, that the question of the relative food values of white and brown bread has to be reconsidered. Vitamin *B* is not richly distributed among foodstuffs. Yeast and yolk of egg are the only important sources from which it is drawn, besides the germ and bran of grain, although it is present in small amounts in meat, milk, potatoes, green vegetables, and some fruit juices.

White and brown bread. Disregarding the presence or absence of vitamins for the moment, the relative values of white and brown breads of various kinds will depend mainly on the extent to which they are digested, the heat value of the digested part, and the percentage of protein in the particular bread. White bread contains very little of the germ of wheat, the aleuron layer or the seed coverings. Brown bread contains varying amounts of these ‘offals’, according to the manner of manufacture of the flour from which it is made.

Generally speaking, the darker it is, the more completely is the whole of the wheat grain incorporated in it. The fibre present in bran contained in brown bread is not digested, and it prevents, to a small extent, the complete digestion of the remainder of the

bread. The percentage of bran in even coarse brown breads is, however, small, for the whole grain of wheat contains no more than 2 per cent. of fibre. Brown bread is therefore less completely digested than white.

On the other hand brown bread, while it is not so completely digested as white, frequently contains a slightly higher percentage of protein, for the bran of wheat is rich in protein and the germ extremely rich in protein, containing about 30 per cent., although the quantities of these substances present will be very small. In consequence, the advantage which white bread seems to gain from its more complete digestion is about outweighed by its possible lower content of protein.

Considering now the presence or absence of vitamins in bread, the chief point is that white bread does not contain any vitamins, unless the yeast which is added in its making supplies an appreciable amount, and this is doubtful. Brown breads, on the other hand, will contain some vitamin *B*. Hovis bread is remarkable from the fact that in its manufacture the germ extracted from the manufacture of other white flour is cooked and incorporated into the Hovis flour. Its protein and fat content are thus increased and vitamin *B* is perhaps supplied.

Feeding stuffs. In arriving at the food value of feeding stuffs for stock, precisely similar considerations govern the problem. The food value is dependent on: (*a*) the extent to which the particular food is digested by the particular animal; (*b*) the amount of energy which the digested part yields; and (*c*) the percentage of protein present in the food. The first two factors are expressed together by a figure for each foodstuff and for each animal, known as the starch equivalent per 100 lb. Thus the starch equivalent per 100 lb. of several cereal feeding stuffs for milch cows is as follows: oat straw 17·0; barley straw 19·5; maize 81·4; oats 59·5; maize germ meal 85·3; wheat middlings 70·0. These numbers express the net energy derivable from 100 lb. of the foodstuff by the particular animal. One starch equivalent is referred to as a food unit.

The third factor, namely, the amount of digestible protein in the foodstuff, is given as the Nutritive Ratio. This figure is obtained by adding together the percentage of digestible carbohydrates and $2{\cdot}3 \times$ digestible fat, and dividing into the percentage protein. The ratio for some of the common cereal feedings stuffs is

as follows: oat straw 1/39; barley straw 1/52; maize 1/11; oats 1/7; maize germ meal 1·/7; maize gluten feed 1/3; maize gluten meal 1/2; wheat middlings 1/4·5; wheat bran 1/5.

The requirements of various animals for various productive purposes have all been carefully investigated, and by using the starch equivalent and the nutritive ratios of the various foodstuffs available, animals may be scientifically rationed for meat and milk production.[1]

[1] See T. B. Wood, *Animal Nutrition*, 1924.

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